A SPATIAL ANALYSIS OF DENGUE FEVER AND AN ANALYSIS OF DENGUE CONTROL STRATEGIES IN JEDDAH CITY, SAUDI ARABIA

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Abstract

Dengue fever poses a constant serious risk and continues to be a major public health threat in Saudi Arabia, particularly in the city of Jeddah where, since 2006, despite formally introduced Control Strategies, there has been a significant increase in the number of cases. International literature suggests that a range of variables can influence the persistence of dengue, including climatic conditions, the quality of the urban environment, socioeconomic status and control strategies.

The overall aims of this research are to understand neighbourhood influences on the pattern of dengue fever across Jeddah City and to make a preliminary determination of the enabling factors for, and barriers to, the effective implementation of the Control Strategies for dengue fever in Jeddah City.

A mixed methods research design using quantitative and qualitative data was used. Quantitative data were obtained from administrative sources for dengue fever cases and some of the spatial and temporal variables associated with them, but new variables were created for neighbourhood status and the presence of surface water. Qualitative data are drawn from key informant interviews with 15 people who were, or who had been, working on dengue fever Control Strategies. A qualitative descriptive analysis was based on pre-determined and emergent themes.

The spatial and temporal analysis of the variables related to dengue fever in Jeddah City neighbourhoods revealed that neighbourhood status has a direct relationship with dengue fever cases, which is mediated through population density and the presence of non-Saudi immigrants. While there was no relationship with the presence of swamps, seasonal variations in the incidence of dengue were most pronounced in neighbourhoods of low socioeconomic status. The qualitative review of dengue Control Strategies indicated five themes: (1) workforce characteristics and capability, (2) knowledge about dengue fever in Saudi Arabia and Jeddah City, (3) operational strategies for dengue fever control in Jeddah City, (4) the progress of implementation, and (5) overall view of the Government strategies in Jeddah City. This analysis found that the Strategies were well regarded but that aspects of implementation were not always effective. Nevertheless, both quantitative and

qualitative results showed the persistence dengue fever problems in Jeddah City neighbourhoods and suggested how cases might be controlled.

The number of dengue fever cases in Jeddah City neighbourhoods could continue to rise if the direct and indirect variables affecting dengue fever at the neighbourhood level are not well controlled. Careful attention to the further monitoring of patterns of dengue and specific neighbourhood Control Strategies are recommended, and established Control Strategies need to be implemented as designed. Nonetheless, there is still a need to develop new approaches that can examine and address neighbourhood level issues of dengue fever control.

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This thesis is dedicated to my father Ali Ibrahim, my mother Sheicka Saeed and my sister Areej Ali.

Chapter 1: Introduction and Background

1.1 Introduction

In this thesis, the spatial and temporal trends of dengue fever in Jeddah City are examined in relation to a range of environmental and social variables, and the strategic response of national and local authorities is evaluated. The purpose of this chapter is to provide an introduction and background to dengue fever, its causative agent and diagnosis, as well as what is currently known about dengue fever worldwide, in Saudi Arabia, and in Jeddah City. A conceptual framework for the analysis of dengue fever is developed. At the end of this chapter the aims, objectives and the structure of the thesis are presented.

Dengue fever is a viral disease which is transmitted from person to person via the *Aedes aegypti* and *Aedes albopictus* mosquitoes (Egger, Ooi, Kelly DW, ME, & Colemana, 2008; Guha-Sapir & Schimmer, 2005; Heymann, 2004; Winch et al., 2002). Dengue ranges from classic dengue fever to dengue haemorrhagic fever to the most serious type, dengue shock syndrome (Egger et al., 2008). Clinical features of dengue fever include high fever, severe headache, pain behind the eyes, joint pain and nausea. Dengue haemorrhagic fever is similar to dengue fever but with the addition of haemorrhage which has symptoms similar to dengue fever but may also include severe pain in the abdomen, bleeding, vomiting with or without blood, black stools, and excessive thirst (WHO, 2008). It has been speculated that the word "dengue" may have come from Swahili, and means "caused by evil spirit". Alternatively, it may have come from the Spanish word "dengue" that originally came from the Swahili word "dinga" which means "fastidious" or "careful". It is possible that this word was used to describe the way a person walked when he or she had dengue fever. It has also been defined as "bone breaking" because severe joint and muscle pain are part of the symptoms (Aburas, 2007).

In the Arab world, dengue was first seen in the late 19th century. Dengue emerged in Zanzibar in Dar es Salaam, on the East African coast, and in Makkah, Medina, and Jeddah, Saudi Arabia (WHO, 2002c). In the 21st century, over 50 to 100 million cases annually have been estimated by the World Health Organisation (WHO) in more than two fifths of the world's population who are susceptible to the disease (WHO, 2008, 2009a). Hence, today it continues to be an area of public health concern (Gibbons, 2002; DJ. Gubler, 2002).

Dengue fever has reappeared globally as one of the world's most infectious diseases. Approximately two-thirds of the world's population live in areas where the virus is found (Claro, Tomassini, & Rosa, 2004). It is an important cause of fatalities in tropical and subtropical areas of the world (Endy et al., 2002). Possible reasons for the re-appearance of the disease may be increasing occurrences of global trade and travel, and rising levels of urbanisation (Claro et al., 2004).

Historically, dengue has caused health problems worldwide, with widespread epidemics from the 17th to the 20th centuries (DJ. Gubler, 1997b; Monath, 1988; Soper, 1944), with reports in medical literature in 1779 and 1780 (DJ. Gubler, 1997b). In the years during and after World War II, the flow of soldiers and refugees allowed for vectors and viruses to be introduced to different parts of the world. This tendency has continued with the development of international transport. Because of this, yearly epidemics have appeared in areas such as Central and South America, the Pacific Islands, South East Asia and there have been occurrences of outbreaks in North Australia (Rogers, Wilson, Hay, & Graham, 2006).

There is a widespread belief that severe forms of dengue were first seen in recent times, in the 1950s, in Southeast Asia. It was evident then that it had become a grave public health problem (J. Gubler & Kuno, 1997); however, it was not a new occurrence. There is historical evidence that it had appeared in various parts of the world including the French West Indies, Batavia and Cairo in 1635 (D. J. Gubler et al., 1979; Sabin, 1959), Philadelphia in 1780 and later on the Swahili coast of East Africa, and Australia (J. Gubler & Kuno, 1997).

1.2 Epidemiology of dengue

Dengue has been an important public health problem that has cost millions of dollars for its treatment, prevention and control. A variety of studies have been conducted that closely examine dengue fever in endemic areas around the world. It is one of the most significant viral diseases affecting people around the world. Every year approximately 50 million cases of dengue fever occur worldwide (Farrar et al., 2007). Dengue fever is considered to be one of the fastest spreading mosquito-borne viral diseases worldwide. During the past five decades, the number of cases has increased 30-fold and has expanded its range to new countries and has shifted from mainly urban areas to rural locations (WHO, 2009b). It is a chief cause of morbidity in tropical and subtropical areas of the world (Endy et al., 2002). It has become such a major concern that the WHO in 2005 came together and discussed a possible revision of the International Health Regulations which declares dengue as an example of a disease that may be a public health emergency of international concern and it may compromise the health of people and become an epidemic found in many parts of the world (WHO, 2009b).

Dengue's pattern of distribution changed in tandem with the ecological disruption South East Asia experienced in the aftermath of World War II. Its first known epidemic appeared in the city of Manila in the Philippines in the mid-1950s, and over the next 20 years, it spread throughout Southeast Asia. In the mid-1970s, dengue became known as the leading cause of deaths and hospitalisation among children in that area. In the 1980s and 1990s, dengue continued to strengthen and spread to the west into India and neighbouring countries. It had also expanded to the Pacific Islands in the 1970s and 1980s, and then into the tropical areas of the Americas in the 1980s and 1990s (DJ. Gubler, 1997a).

The spread of the dengue fever was closely aligned with the global spread of the *Ae. aegypti* mosquito that may have originated from Africa (DJ. Gubler, 1997a) . This may have been a result of the expansion of shipping and commerce in that part of the world, as this increased the chances of spreading diseases by increased travel from endemic to non-endemic areas (DJ. Gubler, 1997b). According to Powell et al. (2013) *Ae. aegypti* most likely spread to other areas on ships where conditions were conducive to this type of mosquito. It is believed that the species may have already become domesticated prior to its spread or it had become domesticated as a result of transport. It is likely the mosquitoes were widespread in northern Africa prior to the existence of the Sahara Desert (Powell & Tabachnick, 2013). Despite their origin, the viruses seemed to have been spread to populated areas by humans or by monkeys who had been exposed in the forest. Monkeys are very important hosts for diseases because monkeys move around from area to area and wander into areas where humans can catch their diseases. Gubler also reported that the virus made its way to port cities and then onto ships and barges. Because these ships travelled all over the tropical world, they were spreading the mosquitoes and the diseases that accompanied them (D. J. Gubler, 2004).

The number of cases has increased around the world since the 1970s because of the incursion of infectious genotypes entering new areas as well as a higher level of vector distribution resulting from the unpredictability of urbanisation, the migration of people leaving the countryside to the cities, insufficient management of wastewater, and a lack of vector control programmes (Gibbons, 2002).

Climatic variables have also played a vital part in the transmission of the dengue virus. For example, in the state of Oaxaca, Mexico, it appears that the temperature and the rainy season are closely linked in the vector's development (Gunther, Ramirez-Palacio, Perez-Ishiwara, & Salas-Benito, 2009). Moreover, in Puerto Rico, it was reported that there have been yearly fluctuations of dengue cases influenced by an increase of rainfall, whereas temperature was related to the year to year changes in dengue cases (Jury, 2008).

In addition to climatic factors, social and behavioural variables have also been an integral part of the transference of dengue virus. An example of this can be found in areas such as Queensland, Australia where it is warmer and more tropical. The people in that region switched from rainwater tanks to reticulated water supplies and, as a result, there was a reduction in the presence of *Ae. aegypti* (Jansen & Beebe, 2010).

1.3 The cost of dengue

Dengue has had a significant impact on many populations in endemic areas in terms of causing a health, economic, and social burden. An eight country study in 2005-2006 included five countries in Central and South America (Brazil, El Salvador, Guatemala, Panama, and Venezuela) and three countries in Southeast Asia (Cambodia, Malaysia, and Thailand) (Suaya et al., 2009). The studies were performed to determine the hardship caused by the disease and the costs of dengue illnesses. Studies of the costs of dengue illness measure the economic value of resources lost due to disease or used in its treatment, prevention, and care of those with dengue fever. Calculations included the number of work days lost by those affected and the medical costs (Suaya et al., 2009).

Taking into account that other family members and friends who help care for the dengue patient are often infected by the illness, it has been estimated that 14.8 days are lost from work for non-fatal ambulatory patients and 18.9 days are lost for patients who are hospitalised (Suaya et al., 2009). It was also determined that the average total cost of a non-fatal ambulatory case was about USD 514, whereas the cost of a non-fatal hospitalised patient was around USD 1,491 per case. The total cost of a dengue case combining ambulatory and hospitalised stages was approximately USD 828. When the mean annual numbers of reported dengue cases between 2001-2005 (532,000 cases) from all eight countries studied were examined, the total official cost of reported dengue was calculated as USD 440 million. This is a conservative estimate because it does not take account of unreported cases nor the additional costs of dengue surveillance and vector control programmes (Suaya et al., 2009). Suaya et al.'s research revealed that a treated dengue case inflicts significant costs both on the health system as well as the whole economy.

One of the countries adversely affected economically from dengue was India. It suffered an economic deficit of USD 3 per day at public hospitals and USD 10 per day in private ones because of dengue fever (Sundar & Sharma, 2002; World Bank, 2007). The average annual burden on both private and public sector health services was believed to be at USD 21.7 million. It has been suggested that most economic losses borne by third world countries, such as India, are because of particular preventable diseases, like dengue (Garg, Nagpal, Khairnar, & Seneviratne, 2008).

Puerto Rico's dengue epidemic in 1977 caused a total burden of USD 6 million-USD 16 million in medical costs and control measures. By 1994 the Puerto Rican epidemic had cost in the vicinity of USD 12 million for medical care alone (Rodriguez, 1997; Von Allmen, Lopez-Correa, & Woodall, 1979). Cuba had an epidemic in 1981, the cost of which was estimated to be USD 103 million, with almost half that amount used to control the mosquito population (Rodriguez, 1997). Thailand also experienced an economic burden of between USD 31.5 and USD 51.5 million per annum, depending on the level of epidemic activity each year (Kouri, Guzman, Bravo, & Triana, 1989). An estimated 45% of the expenses were paid by the patients and their families, greatly contributing to an economic burden on the community with consequent social impacts (Okanurak, Sornmani, & Indaratna, 1997).

The costs of dengue control programmes can also be estimated. For example in Jeddah City, in 2006, the number of dengue cases increased significantly, and the Saudi Council of Ministers distributed more than 1.42 billion Saudi Riyals (SAR) (USD 378,000,000) for the development of a policy framework for examining dengue fever in Jeddah City and for dengue control among three organisations: the Jeddah Municipality and Ministry of Health and Ministry of Agriculture (Alharthy, 2007).

1.4 Dengue in Middle East, Saudi Arabia and Jeddah City

Dengue fever has been typically known as a tropical disease found in the jungles of South America or Indonesia; however, there have also been a number of outbreaks of dengue in the Middle East, in countries such as Egypt (Kamal, B, S, S, & P, 1928; Sandwith, 1888), Oman (Mohammad et al., 2008), Yemen (Saad et al., 2005), Kuwait (Cunningham & Mutton, 1991; Lopez-Velez, Perez-Casas, Vorndam, & Rigau, 1996; Mills & Jones, 1991; Morita et al., 1994) and Saudi Arabia (Fakeeh & Zaki, 2001). The earliest outbreak was recorded in 1799 in Egypt (WHO/EMRO, 2005). Dengue emerged more widely in the late 19^{th} century, first in Zanzibar, on the East African coast, and in Makkah, Medina, and Jeddah Cities in Saudi Arabia (WHO, 2002c). Today dengue fever continues to be an area of public health concern (Gibbons, 2002; DJ. Gubler, 2002), with recent outbreaks documented in 2005 and 2006 in Egypt, Oman, and Yemen (WHO/EMRO, 2005). Like Egypt, Oman has a favourable environment in which mosquitoes can thrive. The number of cases in Yemen has risen due to the rising frequency and spread of epidemic dengue. Kuwait sees a number of tourists and this increases the probability of the country being a host to dengue fever.

The first reported case of dengue fever in Saudi Arabia was in Jeddah City in 1994 (WHO, 1995a). Two cases were reported in March 1994: one was described as being grade two dengue haemorrhagic fever, and the other as dengue shock syndrome. Within six months, there were 315 confirmed cases, but without any fatalities. Since that time, dengue fever has been considered to be endemic in Jeddah City (Alharthy, 2007). Although dengue fever may have occurred in other cities in Saudi Arabia, particularly in the west of the country and to the south near the border with Yemen, no official reports are available for the rest of the country.

From the first documented instance of dengue fever in Jeddah City in 1994, there have been 7,360 cases, with the risk of dengue increasing markedly since 2006 until the current year. The attack rate (Attack rate = Number of cases/Total population of Jeddah City in

2010 x 10,000) is shown in Table 1.1. From 1995 to 2003 only occasional cases were reported, with between 2 and 36 cases each year, but in 2004, dengue fever cases dramatically increased to 291 and then again to 1,307 cases in 2006. As a result of such a dramatic increase the Saudi Government took drastic action to control the disease by undertaking many projects and by 2007 only 243 cases were reported. That low number did not exist for long because in 2008, 807 cases were found, more than three times that of the previous year. In 2009 there were 1,606 cases reported and this was followed by a further rapid increase to 2,244 cases in 2010 (Jeddah Municipality, 2012; Ministry of Health, 2010).

Table 1.1 Number of new cases of dengue fever in Jeddah City, 1994-2010

Year	Cases	Attack rate per 10,000 people
1994	469	137.3
1995	6	1.8
1996	2	0.6
1997	15	4.4
1998	0	0
1999	11	3.2
2000	4	1.2
2001	0	0
2002	14	4.1
2003	36	10.5
2004	291	85.2
2005	305	89.3
2006	1,307	382.7
2007	243	71.2
2008	807	236.3
2009	1,606	470.2
2010	2,244	657.1

Sources: (Jeddah Municipality, 2012; Ministry of Health, 2010)

Jeddah Municipality, the Ministry of Health, and the Ministry of Agriculture have been working on official Government designed control strategies for dengue fever in Jeddah City since the 2006 outbreak. Up until 2010, these control strategies had not resulted in any sustained decrease in the number of dengue fever cases. The attack rates decreased from 383 per 10,000 in 2006, to 71 per 10,000 in 2007, but then progressively increased from 236 per 10,000 in 2008, 470 per 10,000 in 2009, to 657 per 10,000 in 2010. This suggests a need to examine both the factors influencing dengue fever in Jeddah City neighbourhoods, as well as the effectiveness and efficiency of Government control strategies that have been implemented to date.

1.5 The development of a conceptual framework for examining dengue fever in Jeddah City

1.5.1 The need for a conceptual framework

A conceptual framework is a useful tool that uses ideas and principles taken from significant fields of investigation (Reichel & Ramey, 1987). Such frameworks are important because they act as starting points to help guide the researcher in the study design and interpreting findings (E. G. Guba & Lincoln, 1989). For this thesis a conceptual framework underlying dengue containment programmes, particularly in Saudi Arabia will help provide the structure for an understanding of the important elements of dengue fever and the various inter-relationships. The framework will also help in the development of an in depth approach to the literature search. Specifically, it will provide clear relationships between the literature and dengue fever in Jeddah City, inform the design of the research, and contribute relevant elements for methodology, analysis and discussion of data.

1.5.2 International frameworks for addressing dengue fever

First WHO framework and Global Strategy

In 1995, the WHO framework and first Global Strategy created a significant health system framework for the prevention and control of dengue fever (WHO, 1995b). In 2000 the WHO indicated that control strategies could be strengthened through better communication and social mobilisation to persuade people to change or maintain behaviours that would prevent the transmission of the disease. As a result, it developed a guide to assist countries to improve their control strategies (WHO, 2000). The Global Strategy contained five main components Figure 1.1.

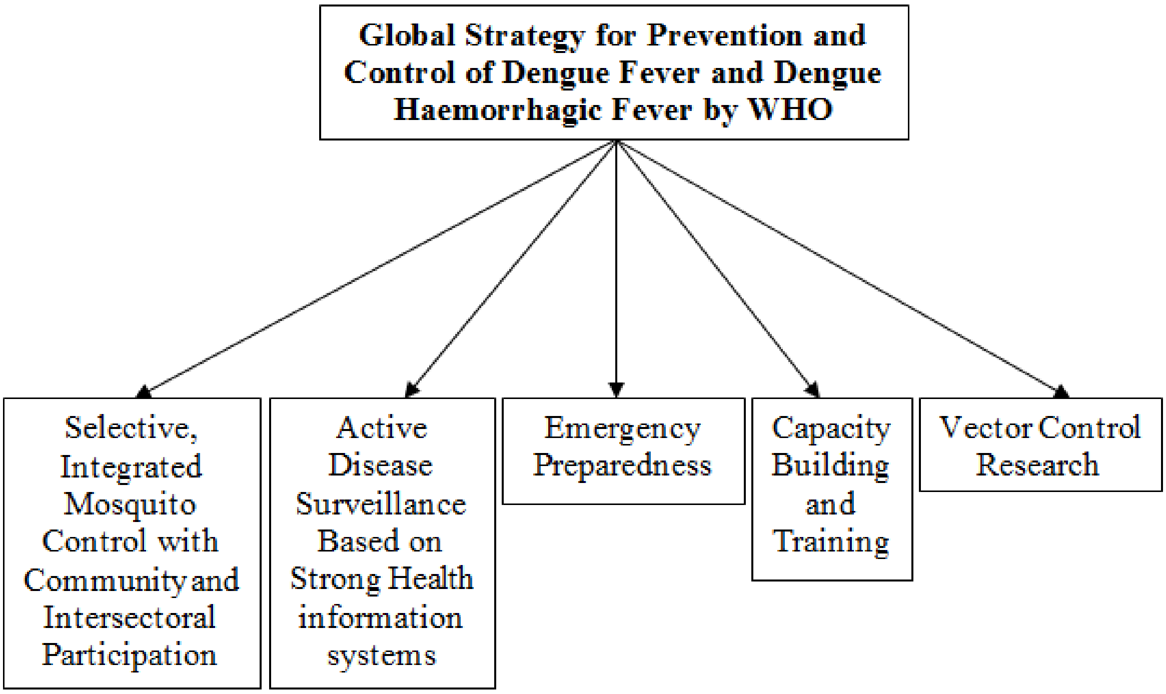

Figure 1.1 Global Strategy for Prevention and Control of Dengue Fever and Dengue Haemorrhagic Fever by WHO (1995)

Source: (WHO, 2000)

The first component comprised carefully selected, integrated mosquito control with community and intersectoral participation (WHO, 2000). Positive examples of this approach can be seen in countries such as Singapore, Cuba and Sri Lanka. An early example of controlling *Ae. aegypti* through community education was set up in 1968 in Singapore (D. J. Gubler & Clark, 1996). This programme was considered to be highly successful because it lowered the *Ae. aegypti* house indices to below 2% (D. J. Gubler & Clark, 1996). In Cuba, an effective programme was established during the 1981 epidemic where Government trained workers went into homes to educate citizens about how to control *Ae. aegypti* (D. J. Gubler & Clark, 1996). In Sri Lanka, surveys conducted before and after educational programmes assessed the extent of improvement in community knowledge and mosquito control. Citizens' knowledge about mosquitoes contributed to disease prevention, independent of sociodemographic characteristics (Yasuoka, Mangione, Spielman, & Levins, 2006). These three examples show that governments working along with the community can produce a positive effect on the incidence of dengue fever.

The second component involved monitoring the active disease, based on health information systems. Disease surveillance alone is not sufficient of itself to control dengue outbreaks. Health information systems, combining both clinical and laboratory investigation, are needed for the early detection of epidemics, surveillance of the vector and assessment of control programmes (WHO, 2000). For example, Taiwan implemented a joint programme involving the participation of central and local governments. Seven different groups worked together to share information on epidemiology, entomology, insecticide application, virology, medical care, source reduction, and health education. Doctors, schools, and individuals were encouraged to report potential cases, with test results released within 24 hours for action by community health bureaux. This sharing of health information combined with clinical and laboratory findings were successful in reducing the incidence of dengue fever (Lei, Huang, Huang, & Chang, 2002). For example the Puerto Rico Department of Health established a surveillance system that successfully predicted epidemics in the 1990s. Unfortunately, little was done to administer effective emergency control until after transmission had reached its peak, although this improved during the late 1990s (Duane Gubler, 2005).

The third component called for emergency preparedness and recommended that emergency preparation include educating health workers, hospitalisation plans, as well as case management and emergency vector control; however, being prepared for an emergency does not guarantee effective control of dengue epidemics (WHO, 2000). Despite preparedness, as illustrated in Sri Lanka which experienced a sudden increase of dengue haemorrhagic fever cases in the 1990s after a period of low incidence. A study by Messer et al. (2002) compared the epidemiology of dengue before and after the epidemic emergence of dengue haemorrhagic fever in 1989 and found no significant differences in dengue or serotype distribution between the pre- and post-dengue haemorrhagic fever emergence period (Messer et al., 2002). Preparedness is seen as important in circumstances when risk might be very high. For example, in Brazil, there was much preparation prior to the Soccer World Cup 2014 to determine the risk of dengue fever for cities where matches would be played (Lowe et al., 2014). Real time seasonal climate forecasts were compiled to predict risk. Risk alerts and thresholds were identified which would allow the Ministry of Health and local authorities to implement control actions before World Cup games (Lowe et al., 2014).

The fourth component involved capacity building and training in surveillance, laboratory diagnosis, case management, and vector control among professional, supervisory, technical, and field staff. Inadequate qualifications or training for workers are identified as one of the main reasons for the lack of success in control strategies, internationally (WHO, 2000). One example of strengthening local capacity to handle environmental issues has taken place in Honduras where the Ministry of Health has created a new category of staff, environmental health technicians (EHT), integrating them into municipal services (Lloyd, 2003). These technicians address environmental problems related to dengue fever and help influence the public health outcomes in the community (Lloyd, 2003).

The fifth component was vector control research which focused on vector biology and control, relationships between diseases, design, and administration of control programmes, including social and economic approaches, and cost–benefit analyses (WHO, 2000). Long-term research into the vector control programme in Singapore, established in the 1960s, suggests that, despite fluctuations in dengue over the decades, success has been based on both epidemiologic and entomologic surveillance data as well as the engagement of the community (Ooi, Goh, & Gubler, 2006). In Argentina, control interventions had much impact on larval indices; however, they failed to keep them below a target level. Despite this, there was sustained community acceptance which may have contributed to averting dengue outbreaks between 2003 to 2006 and restricted the outbreak in 2007 (Gürtler, Garelli, & Coto, 2009).

New ideas from international experience

The first WHO Global Strategy for Dengue Prevention and Control (1995) has been vital for dengue fever control; however, the design of the Global Strategy is now nearly two decades old; moreover it was fairly general so that it could be useful to any country. Over the last decade research and development into dengue fever control has contributed new ideas to the development of dengue control. This research can be summarised in four themes. First, there has been more interest in the role of the community in dengue fever controls, including efforts to build capacity, and a need to understand local factors, conditions and determinants. Second, greater sustainability in programmes needs to be considered. Third, there is also a better understanding of the relationship between dengue fever within health systems. Finally, emphasis on monitoring and programme implementation has been highlighted.

The first theme places emphasis on the role of the community in controlling dengue fever. In a study by Heintze et al. (2007), evidence from 11 studies was reviewed (Ávila Montes, Martínez, Sherman, & Fernández Cerna, 2004; Espinoza-Gómez, Hernández-Suárez, & Coll-Cárdenas, 2002; Fernandez et al., 1998; Kay et al., 2002; Lardeux et al., 2002; Leontsini, Gil, Kendall, & Clark, 1993; Nam et al., 2005; Raju, 2003; Sanchez et al., 2005; W Swaddiwudhipong et al., 1992; Wang, Chang, Wu, & Ho, 2000), to determine the achievements of community based control programmes. Heintze et al. (2007), concluded, "Evidence that community-based dengue control programmes alone and in combination with other control activities can enhance the effectiveness of dengue control programmes is weak" (p.317); however, this does not mean it was "inconclusive." They also suggested in their conclusion that "co-ordinated involvement of local health services, trained vector control personnel, civil authorities and the community could contribute to converting information into practice and encourage communities to take over prevention and control measures. This underlines the importance of inter-sectoral co-operation". It was found that community based interventions had a positive impact on reducing larval indices and dengue disease; however, it was inconclusive whether the combination of community-based control strategies and chemical vector control was able to reduce dengue transmission. Nonetheless, it is suggested that combined interventions are more effective than using only one intervention alone because they can address a variety of barriers (Heintze, Garrido, & Kroeger, 2007).

The second theme addresses the issue of having greater sustainability in control programmes. Despite the number of frameworks available for communicable diseases, there have been no frameworks for assessing the sustainability of community-based dengue control programmes (Hanh, Hill, Kay, & Quy, 2009). Hanh et al.'s review (2009) is the first of its kind to mention a framework for evaluating the sustainability of a dengue control programme. They found only two previous articles that had frameworks for assessing project sustainability (Hanh et al., 2009). These frameworks measured maintaining health benefits, continuing programme activities, and long-term capacity building in the community and applied them to the Huan Phong commune in Vietnam. It was found that successful interventions included change at many levels, such as individual, organisational, and institutional. Furthermore, a set of criteria for evaluation was identified as being required to assess progress after a project has ceased. Hanh et al. (2009) established 13 criteria and a five interval sustainability score to assess and compare the sustainability of a project at different times. This enables sustainability frameworks to assess long-term contributions of project activities to dengue or other vector control programmes (Hanh et al., 2009).

The indicators of sustainability can be grouped into three types of measures. One type involves measuring the health benefits of people after the financial resources have ended for a particular programme. The second type concerns inquiries regarding the continuation of programme activities within an organisation, which may often develop into a regular, routine procedure also known as “routinisation”. A programme may continue to exist and implement activities, but whether the outcomes for its participants are measurable may be questionable. The last type of measure involves questions about the continued capacity of the community to develop and implement health promotion programmes (Scheirer, 2005).

The third theme stresses the importance of the health service system and its relationship to dengue control. Among various countries, there are documented differences in health outcomes. Some of these differences stem from a variation in the performance of the national health system (Arah, Klazinga, Delnoij, Ten Asbroek, & Custers, 2003). Each system may come with its own design, content and management which means that health outcomes can vary widely. It is, therefore, essential that governments assess their own health care performance (Murray & Frenk, 1999). Many countries have renewed their interest in how their health systems operate and many have developed performance indicators for monitoring, measuring, and managing different health systems to achieve optimal quality (Arah et al., 2003). As health systems are different, so too are the frameworks for the control of dengue fever that can be designed for different dengue fever scenarios.

The fourth theme identifies that monitoring and evaluation of programme implementation is of vital importance. There are a variety of frameworks and methods used to assess and monitor health systems and individual services or policies within those systems and evaluate their implementation. The WHO recognises the importance of monitoring implementation, but that it is extremely difficult. A study by Atun et al. (2004) investigates a conceptual model and toolkit for rapid assessment and monitoring of a health system and infectious disease programme including horizontal and vertical assessment. Horizontal assessment is used to analyse the health system from a range of angles within which the infectious disease programme is ingrained. Vertical assessment measures specific components of the infectious disease control strategy (Atun, Lennox-Chhugani, Drobniewski, Samyshkin, & Coker, 2004).

These ideas are reflected in the Infectious Disease Framework (CDC) (CDC, 2011). While this Framework addresses a broader range of diseases than dengue fever, it recognises vector borne diseases as important, and there are elements in the CDC Infectious Disease Framework which relate to recent thinking on dengue fever control. These include: the need to strengthen public health fundamentals, including disease surveillance, laboratory detection, epidemiologic investigation, a more co-ordinated approach among agencies, and an emphasis on evaluation (CDC, 2011).

The New WHO framework and Global Strategy, 2012-2020

The Global Strategy for Dengue Prevention and Control 2012-2020 draws on the earlier Global Strategy of WHO 1995 and also research from the past decade, set out above. It provides a more comprehensive approach to dengue fever control than the earlier Global Strategy, including setting goals and objectives for the reduction in dengue worldwide (WHO, 2012). Five technical elements, along with five “enabling” factors form the basis of reducing the burden of dengue (Figure 1.2).

The technical elements set out in Figure 1.2 all relate to reducing the incidence of dengue through clinical and public health management and research. The first element involves diagnosis through laboratory confirmation and case management with training of all medical and non-medical staff. The second element involves integrated surveillance and outbreak preparedness by relevant sectors and agencies. This comprises epidemic response as well as programme evaluation. Sustainable vector control is the third element which strives to reduce transmission and morbidity attributable to dengue. The fourth element is future vaccine implementation because dengue prevention and control strategies should include vaccines as a crucial component to anticipating and preparing for any outbreak. The last element emphasises basic, operational and implementation research needed to support the objectives of the Global Strategy.

This final technical element is different from the other elements in that it utilises in part a geographical perspective on research for local interventions for the efficacy of human and entomological surveillance, water concerns, conditions supporting human behavioural changes, models for determining susceptible groups or geographical areas, and appraisal of settings in choosing approaches (WHO, 2012). Recent research shows that on the local level, neighbourhood problems can influence dengue fever cases (Heintze et al., 2007; Lloyd, 2003). For Jeddah City local research can include consideration of neighbourhood level influential factors, and use of geographical analysis to understand their impact and the effectiveness on dengue fever cases.

In addition to the five technical elements outlined above, there are five enabling factors which support implementation of the Global Strategy. These are: (1) advocacy and resource mobilization; (2) partnership, coordination, and collaboration; (3) communication to achieve behavioural outcomes; (4) capacity building; and (5) monitoring and evaluation. These factors require collaboration at all levels of government and other sectors in order for them to be effective (WHO, 2012).

All these enabling factors concern the way in which a strategy can be examined and reviewed to understand the quality of the strategy and what can be done now and in the future. A number of studies have evaluated the Global Strategy for Dengue Prevention and Control (Arah et al., 2003; Atun et al., 2004; Hanh et al., 2009; Scheirer, 2005). Jeddah City has its own strategies, based on the WHO 1995 Global Strategy. Those new enabling factors can be helpful in evaluating the Control Strategies for dengue fever in Jeddah City.

Both the 1995 and 2012-2020 WHO Global Strategy for Dengue Prevention and Control were similar in that both presented a comprehensive approach and can be applied globally. The new Global Strategy, however, incorporates more modern research and thinking than the earlier 1995 WHO Global Strategy. Two areas of the recent WHO Global Strategy have been identified as important for dengue fever research in Jeddah. The first of these is the importance of the local geographical level and the factors that influence the distribution of dengue fever cases at the neighbourhood level. The second area is the evaluation of dengue control strategies including an analysis of the barriers to their effective implementation in different social environments. Both of these elements inform the current project.

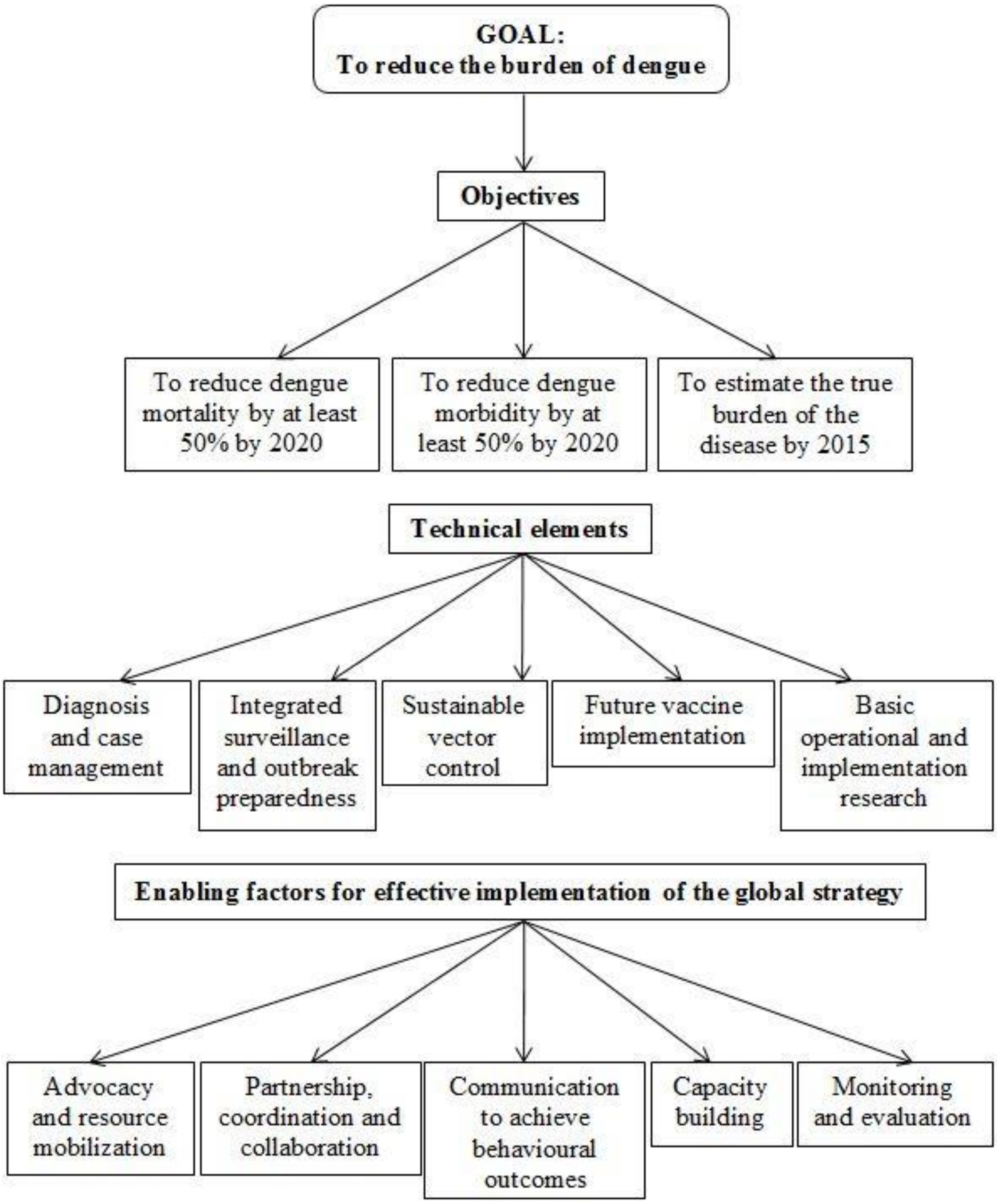

Figure 1.2 Global Strategy for Dengue Prevention and control by WHO, 2012-2020

Source: (WHO, 2012)

1.6 Aims of the research and structure of the thesis

This chapter has shown that dengue fever is an important public health problem worldwide, with significant costs to health services and the community. The expansion of dengue fever in Saudi Arabia has been highlighted, particularly the critical situation in

Jeddah City. It has also shown that there have been important WHO initiatives to develop plans to combat dengue fever internationally.

The overall approach of this research is based on the framework of the WHO Global Strategy 2012-2020, a review of the international literature (Chapter 2), a more detailed analysis of the occurrence of dengue fever in Jeddah City (Chapter 3), and a scan, also set out in Chapter 3, of the current official Control Strategies that have been put in place.

As noted in section 1.5, the WHO Global Strategy identifies local analysis as an important area of research in order to better understand patterns of dengue fever and to design appropriate interventions. The review of the international literature in Chapter 2 supports this, and points out that most local level research concentrates on climatic variables but that research that considers the social environment, or the interaction between the social and physical environment and dengue fever, is limited. A scan of dengue fever in Jeddah City using available data (Chapter 3) is unable to address this aspect of dengue occurrence. It can be concluded, therefore, that localised geographical research, taking account of both social and physical environmental factors at the neighbourhood level, can make an important contribution to understanding the patterns of dengue fever in Jeddah City.

The WHO Global Strategy (see Section 1.5) also identifies some of the key factors that can support and improve the effectiveness if interventions for dengue fever control. Chapter 2 (Section 2.5) considers the extent to which “top-down” or “bottom-up” policy approaches can contribute to effective interventions, with international research indicating that combinations of these approaches, suited to local circumstances, is likely to be most useful. A presentation of the scope of Control Strategies for Jeddah City is set out in Chapter 3, but there is, as yet, no appraisal of the way in which these have been implemented.

Aims of the research

In view of the guidance of WHO, a review of the literature and initial investigations in Jeddah City, the overall aims of this research are to assess the social and physical environmental neighbourhood influences on the pattern of dengue fever, and make a preliminary determination of progress towards implementation.

Specific research objectives are

- To describe the spatial and temporal trends of dengue fever distribution in Saudi Arabia.
- To assess the relationship between neighbourhood physical and social environmental characteristics in Jeddah City and the distribution of dengue fever.
- To evaluate the response of relevant agencies to the problems of dengue fever in Jeddah City.

Structure of the thesis

Chapter 2 contains a literature review of the background to dengue fever, the global research into dengue, factors facilitating its spread, and the global experience of efforts to control it. The chapter reveals that there have been few studies of dengue fever in the Middle East and an absence of studies that investigate social and environmental factors at neighbourhood level together. The chapter develops a model for analysing pathways between neighbourhood socioeconomic status and dengue. This chapter also considers the experience of dengue fever control internationally and some of the tensions between top-down and bottom-up models of policy and implementation.

Chapter 3 examines the distribution of dengue fever in Saudi Arabia, and particularly in the city of Jeddah. The chapter considers the Government's Strategies to control dengue fever in Jeddah. By the end of the chapter, it is clear that a further investigation into both trends and determinants of dengue in Jeddah and a review of the Government Strategies are required.

Chapter 4 sets out specific methods used to achieve the research aims and objectives. This includes discussion of the steps for obtaining, cleaning, and analysing data related to the spatial and neighbourhood analyses of dengue fever, including the creation of new variables for socioeconomic status and standing water. This chapter also describes the qualitative descriptive analysis undertaken to investigate of the Control Strategies for managing dengue fever in Jeddah City.

Chapter 5 sets out the results of the spatial and temporal trends of dengue fever in Jeddah City neighbourhoods and their relationship to neighbourhood social and physical environmental factors.

Chapter 6 presents the results of the interviews with key informants on the dengue Control Strategies in Jeddah. Results are presented according to pre-determined and emergent themes.

Chapter 7 discusses the problem of dengue control in Jeddah in light of the international experience, the available conceptual frameworks, and research undertaken for this thesis. Recommendations for change are made.

Chapter 2: Factors Affecting the Spread and Persistence of Dengue Fever

2.1 Introduction

As discussed in Chapter 1, the Global Strategy for Dengue Prevention and control by WHO for 1995 and 2012-2020 was used to develop the conceptual framework and overall aims of the research. These focus on the environmental factors that have been important in influencing the spread of dengue in Jeddah City and an evaluation of the Control Strategies which have been important in limiting the spread of the disease. In light of the objectives outlined at the end of Chapter 1, the aim of the present chapter is to provide a greater understanding of these two factors.

Chapter 2 is organised as follows. It begins by providing an overview of dengue fever, the viruses associated with it (section 2.2) and the mosquito vectors (section 2.3). This is followed by a review of the national and local neighbourhood factors considered to be important in influencing the spread and persistence of dengue (section 2.4). Section 2.5 considers aspects of dengue control and the problems of policy implementation and how the latter are often shaped by community characteristics. The chapter concludes with a critical review of dengue fever studies that identifies gaps in research, particularly those relevant to the study of dengue fever in Jeddah City (section 2.6).

The main vector of dengue fever is the *Ae. aegypti* mosquito which is present throughout many tropical and subtropical regions. They feed off human blood, primarily during the day, with an almost undetectable bite. It has been found that in comparison to *Ae. aegypti*, *Ae. albopictus* is considered as a minor transmitter of dengue virus. In areas where *Ae. albopictus* are more plentiful than *Ae. aegypti*, there has never been an epidemic with severe cases of dengue (Lambrechts, Scott, & Gubler, 2010). The *Ae. aegypti* mosquito flourishes in tropical areas, especially during the rainy seasons (Gibbons, 2002), but can also breed in areas where there is standing water (Lifson, 1996).

While humans are the main carrier for the virus, non-human primates in Asia and Africa can also be infected (Gibbons, 2002). The disease can be spread by animals and humans travelling to other parts of the world and then bringing it back with them to populated areas.

2.2 Dengue fever and dengue viruses

2.2.1 Dengue fever

Dengue fever, often quite a benign disease, occurs as a sudden onset of fever that may last from three to seven days. Severe muscle and joint pain, headaches and rashes may accompany a persistent fever (Murgue, 2010). Other symptoms may include nausea, vomiting and weakness (Waterman & Gubler, 1989). No permanent side effects are known, and fortunately dengue fever is rarely fatal (DJ. Gubler, 1997a).

In some instances dengue fever can appear almost asymptomatic; however, it can make the patient feel lethargic and fatigued which can last up to five to seven days. Fortunately, the dengue virus is capable of disappearing from the blood quite quickly, after an average of five days with dissipation of the fever (D. J. Gubler, Suharyono, & Tan, 1981; Vaughn et al., 1997). On the other hand, dengue fever may be accompanied by severe complications such as myocarditis, hepatitis, encephalopathy and neuropathies (Lum, Lam, George, & Devi, 1993; Sumarmo et al., 1978). Travellers who get dengue fever may be incapacitated for a sufficient period of time to prevent onward travel and may even require hospitalisation (T. Jelinek, 2000; Schwartz, Mendelson, & Sidi, 1996).

Dengue haemorrhagic fever is similar to dengue fever, in that the person has a high fever, but in addition they present with haemorrhage (bleeding) and the presence of a low blood platelets count (Fakeeh & Zaki, 2001). Although similar in nature to dengue fever, the consequences of dengue haemorrhagic fever are more severe and sometimes the complications are life-threatening (Hammon, Rudnick, Sather, Rogers, & Morse, 1960). The initial symptoms may be similar to dengue fever, but if the patient has plasma leakage four to seven days after the onset of dengue fever, it has most likely developed into dengue haemorrhagic fever (Gibbons, 2002). The patient may also experience abdominal pain, vomiting, severe joint and muscle pain, restlessness, and changing levels of consciousness (Gibbons, 2002). The fever usually escalates from 38 to 40 degrees Celsius and continues for two to seven days. Dengue haemorrhagic fever and dengue shock syndrome commonly develop around the third to seventh day of the illness (WHO, 1986). The development of dengue haemorrhagic fever gives warnings of an increased chance of shock which means that there are signs of circulatory failure, including narrow pulse pressure, hypotension, or frank shock (Kalayanarooj et al., 1997; J. G. Rigau-Perez, 1997). The patient is treated with intravenous fluids, good nursing care and observation because the patient's status can change abruptly, or even become critical (José G. Rigau-Pérez et al., 1998).

2.2.2 Dengue viruses

Dengue fever is caused by mosquito-borne viruses belonging to the *Flaviviridae* family, genus *Flavivirus*. There are four related viruses: Dengue 1, Dengue 2, Dengue 3, and Dengue 4. Mosquitoes are vectors by feeding on blood from many human hosts during one egg laying cycle (DJ. Gubler, 1988; D. J. Gubler, 1998). The dengue viruses are the only known arboviruses that have completely adapted to human life and live in large tropical urban settings (D. J. Gubler, 1998). They are capable of producing a variety of illnesses in an affected person including a small infection or rash, fever, to severe haemorrhagic disease (D. J. Gubler, 1998; Monath, 1988; WHO, 1997). The fatality rate for the dengue virus is 5% worldwide (D. J. Gubler, 1998; Monath, 1988; WHO, 1997).

The dengue virus's evolutionary history is quite recent. The four serotypes were estimated to have appeared only 1,000 years ago and have caused epidemics in humans only in the past few hundred years (Holmes & Twiddy, 2003). The origin of the virus remains unclear, as does the scope of genetic and phenotypic diversity present in the primate transmission cycle (D. J. Gubler, 1998). Currently, dengue is endemic in more than 100 tropical countries (S. B. Halstead, 1982).

2.3 Dengue vector Aedes aegypti

Aedes aegypti is the main vector species for dengue fever (WHO, 1999). It is widespread in tropical and subtropical areas (Figure 2.1). This vector species is of major international public health concern (WHO, 1998, 2002a) and it is the main vector for dengue fever in Jeddah City .

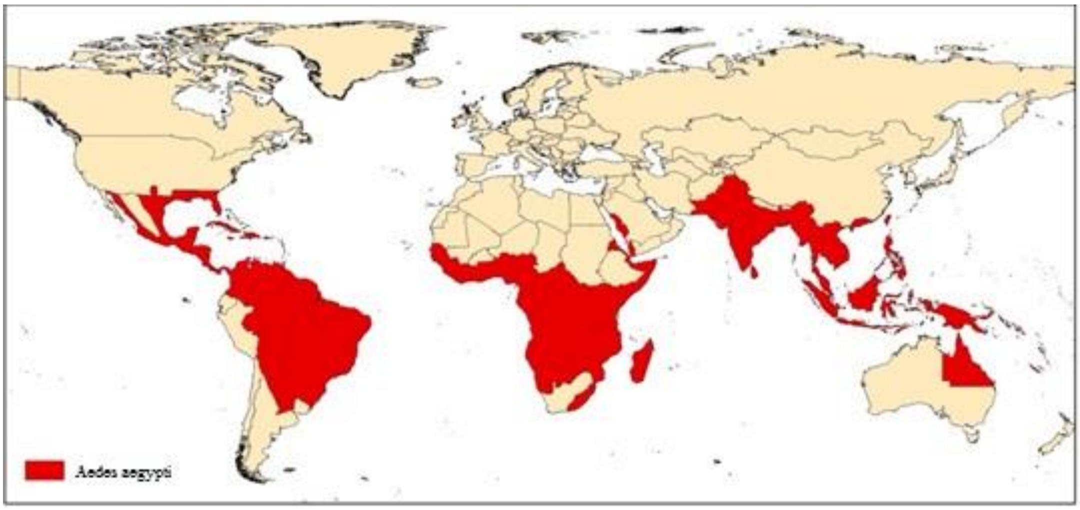

Figure 2.1 Global distribution of Aedes aegypti

Source: Based on data from (Rogers et al., 2006)

The *Ae. albopictus* is believed to have little impact on the transmission of dengue because it does not adapt well to urban environments, and while it will feed on a single person, it is thought to prefer to feed on animals, although this has not been confirmed. (Gibbons, 2002; DJ. Gubler, 2002; D. J. Gubler, 2003; Rodhain & Rosen, 1997). Although the vector *Ae. albopictus* is widely distributed around the world (Figure 2.2) (Knudsen, 1996), it is not found in Saudi Arabia and therefore is not discussed here.

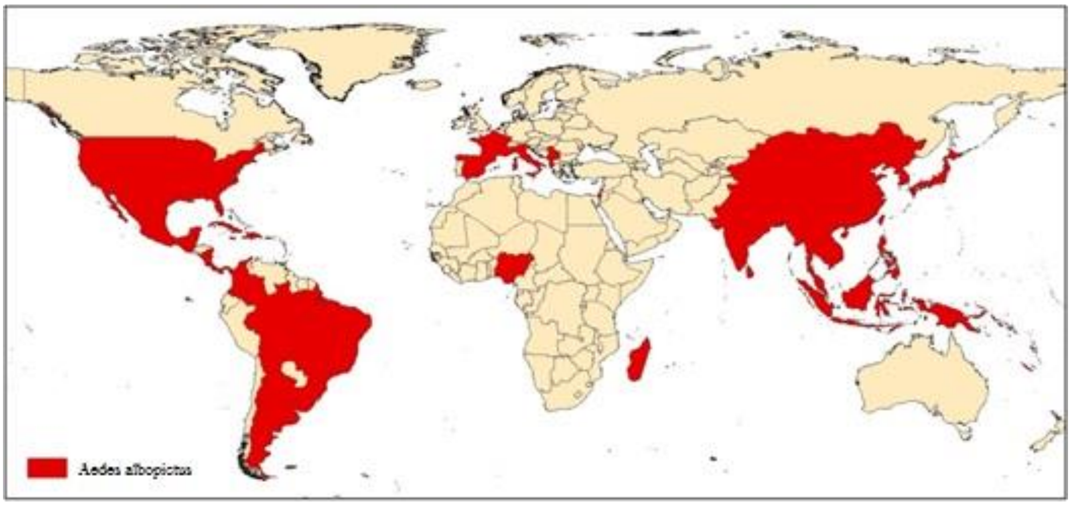

Figure 2.2 Global distribution of Aedes albopictus

Source: Based on data from (Rogers et al., 2006)

Transmission of the virus

The mosquito holds the virus in its salivary glands and when it bites a human to feed, the virus is transmitted into the human's blood stream (S.B Halstead, 1997). As can be seen in the dengue fever transmission cycle, dengue fever and dengue haemorrhagic fever can be propagated when the female *Ae. aegypti* or *Ae. albopictus* bites a person who is already infected and is in the viraemic phase of the illness, which appears two days prior to the beginning of the fever and continues four to five days after its onset (S.B Halstead, 1997). After the female ingests the infected blood meal, the virus reproduces; this then infects the salivary glands and the virus moves into the saliva, causing infection during penetration. The genital track of the female mosquito is also infected and the virus can pass into the fully developed eggs at the moment of oviposition (S.B Halstead, 1997).

Lifecycle and dispersal of Aedes aegypti

The dispersal of *Ae. aegypti* and the emergence of dengue fever have been associated with the development of rural water supply structures and improved transport systems (WHO, 1999). The mosquitoes are most often seen in those urban areas where there is poor water management, the presence of non-degradable tyres, and plastic containers (where standing water accumulates) as well as inaction of the public health community to eliminate mosquito breeding sites (Abdalmagid & Alhusein, 2008).

The eggs of *Ae. aegypti* are laid by adult females on wet surfaces, just above the water line (WHO, 1999). In non-urban environments, the breeding sites are located in places that resemble tree-hole settings and tree stumps. In urban habitats, the mosquitoes lay eggs on small artificial containers such as cans, buckets, flower pots, and bottles in people's yards and inside houses (Otero, Schweigmann, & Solari, 2008). The eggs can survive without water for long periods of time, sometimes for more than a year, and this enables the species to survive during adverse climatic conditions (WHO, 1999).

Aedes Aegypti is found in urban environments and has three immature stages: egg, larvae, and pupae, and then the mature mosquito (Figure 2.3) (Otero et al., 2008). The duration of development from immature to mature depends on temperature, availability of food, and larval density in the breeding site (WHO, 1999). Under optimal conditions, the time taken from hatching to adult emergence can be anywhere from 7 to 10 days including two days in the pupae stage (WHO, 2011). At lower temperatures, however, this can be much longer, up to several weeks (WHO, 1999). The pupae stage lasts from one to a few days depending on temperature (Southwood, Murdie, Yasuno, Tonn, & Reader, 1972). The pupae are able to move around and dive rapidly when disturbed. At the end of this stage, the adult emerges from the pupae skin with a sex ratio of one male to one female (Southwood et al., 1972).

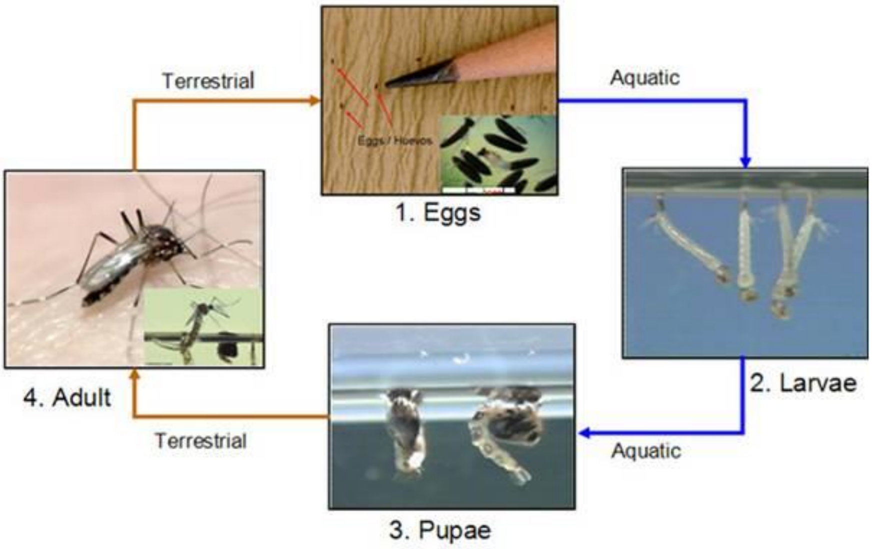

Figure 2.3 Aedes aegypti Life Cycle

Source: (Centers for Disease Control and Prevention, 2013)

For *Ae. aegypti*, one way the transmission cycle can be terminated is if the breeding sites can be controlled effectively at the larval or pupal stages by identifying the possible breeding sites and taking action to remove the chances of a mosquito laying eggs or breeding there. Controlling the life cycle of the vector at any stage can be the way to stop the spread of dengue fever cases.

Shortly after emergence (five to ten days after the eggs have been laid) (WHO, 1988), the adult mosquitoes mate and the inseminated females must have a blood meal within 24 to 36 hours (WHO, 1999). Because they are a diurnal species, females have two periods of biting activity, one in the morning, after daybreak, and the other at dusk, for around two hours (WHO, 1999). There is also a chance they may bite at night if the room is brightly lit. It is only the adult females that are responsible for the spread of dengue fever (Arrivillaga & Barrera, 2004). The average life span is approximately three to four weeks but longer during the rainy season (WHO, 2011).

Flight range of the Aedes aegypti mosquitoes

In order to develop strategies to control the dispersal of adult female *Ae. aegypti* mosquitoes, it is necessary to determine their flight range. It had been estimated that this is restricted to within 30 to 50 metres of the site of emergence (WHO, 2011). As this flight may be driven by the need for the *Ae. aegypti* mosquitoes to distribute its eggs among several breeding sites and blood meals (P. Reiter, Amador, Anderson, & Clark, 1995), it is recognised that the female *Ae. aegypti* mosquitoes can fly over 400 metres to lay all of its eggs. Trpis and Hausermann, (1986), however, have estimated an average daily flight for females of 57 metres, with a maximum dispersal of 154 metres (Trpis & Hausermann, 1986). Rodhain and Rosen, (1997) note that the spontaneous dispersal of adults averages from 30 to 50 metres per day, and females typically only visit two or three houses during their lifetime (Rodhain & Rosen, 1997). Muir and Kay, (1998) measured an average distance travelled overall of 56 metres for females and 35 metres for males, with daily flight ranging from 16.8 metres to 24.7 metres for females and 14.7metres to 18.2 metres for males (Muir & Kay, 1998). It is evident that the females fly further because they are in search of a suitable breeding site. In Iquitos, Peru, a spatial analysis showed that most adults do not fly far from the container where they developed as larvae and pupae (Getis et al., 2003).

The flight range of *Ae. aegypti* can be controlled where the highest density of dengue fever cases are located. Using mosquito traps within the flight range of the *Ae. aegypti* to catch them and stop the spread of dengue fever cases is one method that can show significant results.

Altitude

Altitude is another important factor in limiting the distribution of *Ae. aegypti*. For example, in India, the *Ae. aegypti* mosquitoes can be found from sea level to 1,000 metres elevation (WHO, 1999). At less than 500 metres, there are moderate to heavy *Ae. aegypti* mosquito populations, while at higher elevations, the populations are smaller. In South East Asia, the limit for *Ae. aegypti* distribution is from 1,000 to 1,500 metres (WHO, 1999). In other areas of the world, they can be found at higher altitudes, for example, at up to 2,200 metres in Colombia (WHO, 1999). It is vital to understand the altitude these mosquitoes can reach when determining how to control their distribution. Jeddah City only reaches 412 metres and this low elevation makes it more susceptible to *Ae. aegypti* distribution.

Resting

Approximately 90% of *Ae. aegypti* mosquitoes rest inside people's dwellings or in buildings. They prefer to rest on surfaces that are dark, humid or enclosed, such as bedrooms, closets, and kitchens (WHO, 2011). Keeping houses clean and dry may prevent *Ae. aegypti* from finding a suitable place to live within people's residences.

Breeding sites

One reason for the *Ae. aegypti*'*s* dispersal is the search for breeding sites (Otero et al., 2008). When they are ready to feed on blood and lay eggs, their dispersal is increased (Otero et al., 2008). If the density of breeding sites is high, females are able to find them much more quickly which leads to a short dispersal. If the density of sites is low, then the females must fly longer distances until they find a suitable breeding place (Ethier & Kurtz, 1986; P. Reiter et al., 1995; Wolfinsohn & Galun, 1953).

Model based forecasting of spread of Aedes aegypti

There are three important global models developed by Jetten and Focks, (1997), Hopp and Foley, (2001) and Hales et al. (2002) to forecast the distribution of *Ae. aegypti* and the risk of dengue transmission under various climate change situations (Jansen & Beebe, 2010). The first of the global models is based on the vector capacity and mosquito life-table models by Jetten and Focks. This model was used to understand and predict changes in dengue transmission under present and future climate warming scenarios. Jetten and Focks developed an equation that shows the critical density threshold which estimates the number of adult female vectors required to maintain the virus in a human population. Temperature parameters were used to make predictions for $2^{o}C$ and $4^{o}C$ increases in temperature to determine the adult survival rate, the lengths of time between feedings, and the development of egg batches. Overall, this model aimed to show the current patterns of dengue activity and the potential for increased transmission and expansion through latitude and altitude under increasingly warming temperatures (Jetten & Focks, 1997).

The second attempt at a global scale model is based on the Container-Inhabiting Mosquito Simulation Model, a mosquito life table model that incorporates elements of stochasticity, such as daily meteorological data and variations such as the daily variability of larval food delivery. The results of this model concurred with currently observed global distributions of *Ae. aegypti* where there is an increased latitudinal distribution in the warmer summer months (M. J. Hopp & Foley, 2001).

The third scenario at developing a model is suggested by Hales et al. (2002) and it approximates possible dengue activity using vapour pressure and dengue distribution records between 1975 and 1996 as its base. The amount of humidity was found to be the most important predictor of dengue activity with a significant correlation between humidity and current global dengue activity (Hales, De Wet, Maindonald, & Woodward, 2002).

The historical distribution of this vector can be seen within a global winter isotherm of 10^{o}C that was first described by Christophers, (1960) and is still being used by the WHO to describe the species' geographical limits (Figure 2.4) (Christophers, 1960; WHO, 2009c). Climate variables alone cannot explain the geographical distribution of *Ae. aegypti.* While historical distribution must be taken into consideration (Jansen & Beebe, 2010) other factors, such as trends in urbanisation, infrastructure development, socioeconomic conditions and preventative measures play a major role in the vector's distribution (Jansen & Beebe, 2010). Most of the attempts to explain the potential distribution of this species have failed to use all possible variables (Jansen & Beebe, 2010) and it is crucial to note the significant impact of the role of humans and the environment on the presence of *Ae. aegypti* in the modern world (Jansen & Beebe, 2010).

Impact of humans on Aedes aegypti mosquito breeding and dispersal

One way in which humans can have an impact on the environment of the *Aedes* mosquito is by locating and decreasing the number of breeding sites. A survey by Abdalmagin and Alhusein (2008) set out to determine the presence or absence of potential *Ae. aegypti* habitats in the Eastern Sudan. Typically, *Ae. Aegypti* can be found breeding in many different sites including natural receptacles, such as tree holes, or artificial containers, such as discarded automotive tyres (Chambers, Young, & Hill Jr, 1986; Parker et al., 1983; Rathor, 1996; Tinker, 1964). This survey was undertaken in both urban and rural localities of Eastern Sudan, some of which had already seen infestations of *Ae. aegypti* (Abdalmagid & Alhusein, 2008). In Kassala State, there were many breeding sites of *Ae. aegypti* such as in pots and underground rock holes. Breeding sites were seen as far away as one kilometre from the nearest human habitation. El Gadarief, the other state that was investigated, was free of the vector. The authors confirmed that *Ae. aegypti* were seen in two localities in Kassala State and estimated that the vector had expanded its range in all areas inside Kassala town. They attributed this to the lack of water in the region and the presence in town of receptacles that store water. There was also a tendency for inter-breeding between the *Ae. aegypti* and *Anopheles arabiensis*, the vector for malaria, so the containers holding water were a factor in the distribution of various diseases (Abdalmagid & Alhusein, 2008).

2.4 Factors influencing the spread of dengue fever

Many factors influence the spread of dengue fever. These include: (1) climate variables and climate change, (2) neighbourhoods and socioeconomic levels, (3) global travel and migration, (4) urbanisation and population, and (5) community education and awareness. These factors have been shown through research to have a relationship with dengue fever cases and will be discussed in the next sections.

2.4.1 Climate variables and climate change

Climate variables have long been thought to affect the presence of mosquitoes and dengue fever. Evidence indicates that in the early 19th century Egypt was relatively resistant to dengue fever; however, as a result of sudden climatic changes, in 1907, a dengue epidemic affected the whole country. Egypt experienced substantial rain and thunderstorms which were followed by approximately 30 to 40 cases each day of dengue which presented to the Government Fever Hospital, Cairo, in September 1907. Estimates are that thousands succumbed quickly to dengue (Kamal et al., 1928). By December 1907, the temperatures had dropped and dengue fever cases disappeared because of the cooler temperatures and less rainfall.

The transmission of infectious diseases can be determined by many components, including climatic conditions, such as temperature and humidity (Mahr, 2007). High temperatures and moist conditions help in the breeding of mosquitoes. Therefore, mosquitoes that carry the dengue virus will have increased risk of spreading dengue under those circumstances. The transmission of diseases through mosquitoes is very sensitive to climate variations, with several studies suggesting that climatic factors such as rainfall and temperature affect the density of mosquitoes (M. Hopp & Foley, 2003; Rueda, Patel, Axtell, & Stinner, 1990; Shope, 1991; Zwervers, 1995).

Studies have shown that *Ae. aegypti* are susceptible to extreme temperatures. For example larvae die once water temperatures reach 34˚C and adult mosquitoes start to die at an air temperature of 40˚C (Christophers, 1960). Whilst temperature is an important factor in the development of larval advancement it has been shown that it is not the most useful predictor in regards to the larval amounts in a particular region (Christophers, 1960; Kamimura et al., 2002; Moore, 1985; Rueda et al., 1990). Indeed, other climatic factors including the hours of sunlight and wind velocity may influence mosquito survivability and ecology (Jansen & Beebe, 2010).

There have been a number of studies carried out on dengue and climatic factors. For example, Promprou et al. (2005), in a study of dengue fever haemorrhagic fever incidence rates and climatic factors of southern Thailand, showed that while climatic variables (rain and temperature) do have a major role in the transmission cycles of dengue haemorrhagic fever, the importance of these factors differed by region. The study compared the Gulf of Thailand side of southern Thailand to the Andaman Sea side (Promprou, Jaroensutasinee, & Jaroensutasinee, 2005). The Andaman side with 204 ± 215 mm rainfall and 80.85% humidity had a lower incidence rate of dengue haemorrhagic fever than the Gulf side, which had 183 mm of rain and 79% humidity (Promprou et al., 2005). These variations were because of the high yearly precipitation and the higher number of rainy days on the Andaman Sea side during the May to October monsoon season (Promprou et al., 2005). These findings contrasted with an earlier study by Kanchanapairoj, (2000) which concluded that the incidence of dengue haemorrhagic fever was similar in both regions (Kanchanapairoj, McNeil, & Thammapalo, 2000). The difference may be because the two studies examined different time spans (1978-1997 versus 1993-2002) and covered different areas (four provinces versus all 14 provinces in Thailand).

Nagao et al. (2003), in Thailand (1992-1996) used multiple regression to analyse the impact of four variables (temperature, rainfall, water wells, and tin houses) on dengue fever. An abundance of *Aedes* mosquito larvae was positively connected with house conditions, water supply and transport services. The house index of *Ae. Aegypti* mosquitoes ranged from 40 to 100 in northern Thailand. There was also an increase of rainfall two months earlier and the temperature was also linked with larval ratios (Nagao et al., 2003).

In the Middle East as a whole, no studies were found regarding dengue fever and climate, but some have been found for Jeddah. There was a study of the relationship between the climate factors and *Ae. Aegypti* and climate factors with dengue fever cases in Jeddah between 2007 and 2008 (Al-Ghamdi, Khan, & Mahyoub, 2009). Al-Ghamdi et al. (2009) found that while the relationship between the *Ae. Aegypti* population and relative humidity for 2007 and 2008 was significant (p<0.001). This was not the case with respect to temperature and rainfall. Moreover, the relationship between dengue fever cases and climate factors in 2007 showed no statistical significance except with relative humidity (p<0.001), but in 2008 it was significant with all three climate variables. The study suggested that relative humidity plays an important role in the *Ae. aegypti* population and the presence of dengue fever (Al-Ghamdi et al., 2009). Furthermore, human behaviour was found to have a greater effect on the spread of *Ae. aegypti* in Jeddah City than climate. Three reasons include the inflow of pilgrims from dengue infected areas, water storage, and stagnant water left in open air containers (Al-Ghamdi et al., 2009).

In Jeddah City, temperature, relative humidity and rainfall had an impact on the density of *Ae. aegypti* mosquitoes. Statistical correlation was used for monthly data for 2004-2008 to determine the connection between climate and mosquito density as well as between mosquito density and dengue fever cases (Alshehri & Saeed, 2013). Alshehri and Saeed, (2013) found that there is a statistically significant relationship between the density of mosquitoes and both temperature and relative humidity. Moreover, mosquito density and the number of dengue fever cases were also strongly correlated in Jeddah (Alshehri & Saeed, 2013).

These studies have been presented to provide an overview of dengue fever and climate research from around the world and in Jeddah City. Their differences can help researchers determine the variables involved in the transmission of dengue fever. Some of these variables are more important than others, with the transmission of dengue fever partly dependent on whether *Ae. aegypti* experiences favourable climatic conditions.

A number of researchers attribute the expansion of dengue worldwide to global climate change (Barclay, 2008). Global warming has had an impact on the increasing rate of the development of viruses in mosquito vectors and has intensified their ability to adapt to different climatic factors and environments (Abadalmagid & Alhusein, 2008). This has resulted in the more rapid development of virus bearing mosquito vectors and has increased their ability to adapt to changing climatic circumstances (Abdalmagid & Alhusein, 2008). *Ae. aegypti* itself is quite noteworthy for its ability to adapt to adverse environmental conditions (Christophers, 1960). Examples include the propensity for adult males to find shelter to escape adverse conditions (Jansen & Beebe, 2010).

Hales et al. (1996) argued that the expansion of dengue fever may be a result of the El Nino Southern Oscillation (ENSO) and La Nina events in the South Pacific region where there are many temperature and rainfall anomalies. The warm temperatures and high moisture that accompany ENSO may increase the adult survival rate and also decrease the extrinsic incubation period (S. B. Halstead, 2008).

Many of these suggested relationships between infectious diseases and El Nino events have a reasonable climatic explanation. The high temperatures have an effect on both vector and pathogen but it is possible that flooding and heavy rainfall can reduce mosquito populations by flushing larvae from their habitat in pooled water (McMichael, Woodruff, & Hales, 2006). Humidity coupled with rainfall and presence of water-holding containers can explain the survival of adult mosquitoes.

2.4.2 Global travel and migration

There are three aspects of global travel and migration that impact on dengue fever: the expansion of endemic areas, the impact of individual travellers, and “mass” population movements or events.

Global expansion of endemic areas

Dengue fever has considerably expanded since the 1980s in areas such as the Pacific Islands and Central America. By the late 1990s, dengue had become a problem for many parts of the world such as the Caribbean, South America and Asian countries (WHO, 2011). World travel and migration are among the reasons for the global expansion of dengue fever. It is possible for a traveller to carry various dengue serotypes and strains into regions where mosquitoes, if present, or brought simultaneously, could in turn, spread the infection (WHO, 2009b). It is plausible that *Ae. aegypti* was launched into the New World through trading and ships travelling to different ports (Tabachnick, 1991). In the 1700s, acute outbreaks of dengue virus possibly occurred in Asia, Africa and North America, and over the last two centuries *Ae. aegypti* has been widely distributed across the world’s tropical climate regions (D. J. Gubler & Clark, 1995). South East Asia has encountered increased dengue virus activity since 1945 and, as a consequence, dengue fever is now widespread in the region (S.B. Halstead, 2006; P. Reiter, 2001).

In the past, *Ae. aegypti* were found in various regions between the north January and southern July 10˚C isotherms (Figure 2.4) (J. S. Mackenzie, Gubler, & Petersen, 2004). While *Ae. aegypti* currently has a wide circulation in tropical and subtropical areas, the present circulation does not precisely reflect the maximum range of its prospective distribution according to historical records (Jansen & Beebe, 2010). Overall, the geographical distribution of *Ae .aegypti* is not fixed and has gone through some major changes in a number of continents over time (Jansen & Beebe, 2010).

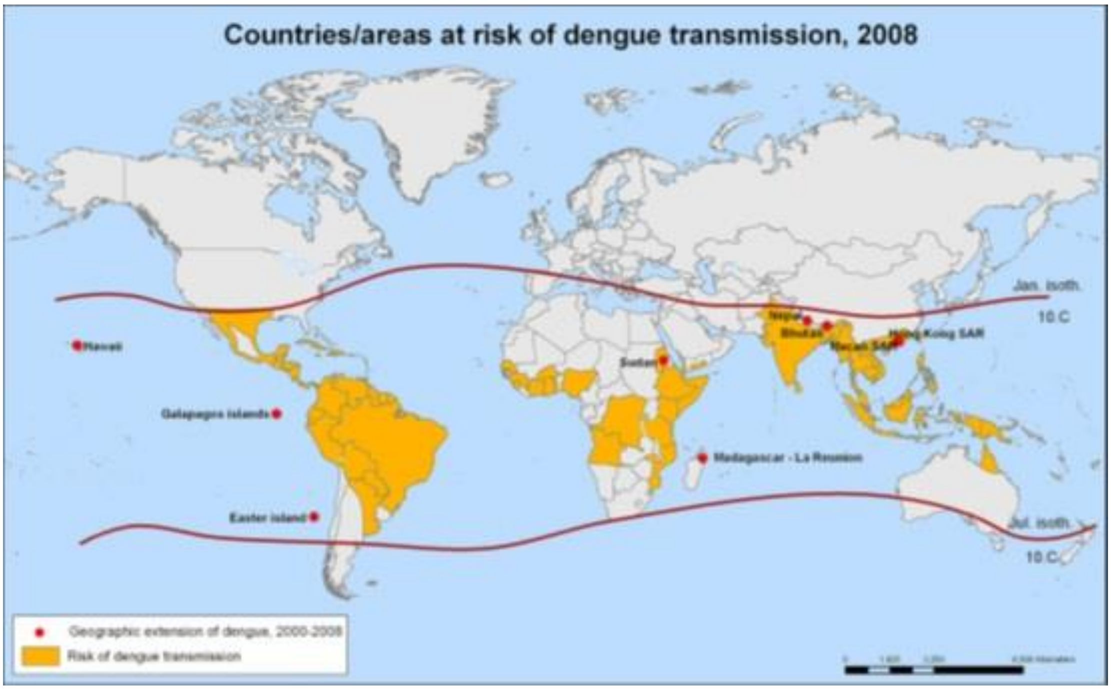

Figure 2.4 Countries at risk of dengue transmission, 2008

Source : (WHO, 2011)

Dengue fever is now also endemic in the Western Pacific regions, Central and South America, and the Caribbean. Epidemic and endemic dengue has grown significantly in the Americas since 1977 (Mortal, 1995; J. G. Rigau-Perez, Gubler, Vorndam, & Clark, 1994). Since the early 1980s it has also spread rapidly from South East Asia to the South Pacific, Caribbean and Latin America going from a few cases of the disease to a hyperendemic situation (Gibbons, 2002).

The impact of individual travellers

In the past the presence of dengue fever among travellers returning ill from their journeys to endemic areas was rare (Meltzer & Schwartz, 2009), but with the popularity of air travel, mass tourism, and migration, the number of travellers who have become infected has risen, causing an increase of epidemic activity (DJ. Gubler, 1997a).

Travellers and migrants have been known to spread dengue to other parts of the world because of their extensive travel from potentially dengue infected areas. Travellers and migrants can potentially act as an early warning sign to other parts of the world, as a traveller may go to a country where there are few laboratories that can test for dengue fever and then arrive home to a country that does have the facilities to test. The latter can advise the former country that it is the location of possible infection. This communication can help form a global database of notifications for public health interventions in other countries (M. E. Wilson, 2003). A steady increase in travel raises the risk of exposure to and distribution of dengue among travellers who may unknowingly acquire the virus and then spread it by travelling to other regions. Travellers returning from dengue endemic or hyperendemic regions thus pose a health risk to areas which have previously been dengue-free (Bulugahapitiya, Siyambalapitiya, Seneviratne, & Fernando, 2007).

A couple of examples from Europe illustrate this potential for spreading the dengue virus to non-endemic areas. A study in Switzerland showed that a small number of Swiss travellers had a high occurrence of antibodies to dengue (Settah, Vernazza, Morant, & Schultze, 1995). Another study of 130 Swiss returnees from Southeast Asia (Tomas Jelinek, Dobler, Holscher, Loscher, & Nothdurft, 1997), revealed that 9 out of 10 patients who tested for dengue had obtained the virus in either Southeast Asia or Western Indonesia (Bulugahapitiya et al., 2007). One patient acquired the infection from Brazil. Other European studies reported on German workers who had returned from Thailand and were found to have antibodies to dengue virus in 4.3% of the returnees (Jänisch et al., 1997). Lastly, Spanish tourists were another group found to be diagnosed with dengue fever after travelling to either Asia, Central America or Africa (Lopez-Velez et al., 1996).

In a study by Antinori et al. (2004), it was found that migrants from Italy, or European residents living in Italy, who travelled to tropical countries for work purposes, have contributed to the number of dengue cases in Italy. Seven percent of all university hospital admissions in northern Milan during the study period were Italians returning from tropical countries, who had contracted fever whilst overseas. Furthermore, dengue fever was one of the most frequent diagnoses recorded in the study among febrile travellers and migrants (Antinori et al., 2004).

Dengue fever is an infectious disease that menaces travellers to disease-endemic areas. In the absence of available vaccines (Hales et al., 2002), pre-travel advice on mosquito protection is essential when trying to reduce the number of dengue fever cases in travellers. A key reason for the recent spread of dengue fever around the world has been dengue-infected travellers returning to their home country from dengue affected countries.

Individual case studies demonstrate the impact travellers can have on dengue fever transmission. One case centred on a man from Oman who had just returned from a two-week vacation in Thailand (Mohammad et al., 2008). Because he had been in Oman for the two weeks before he displayed fever symptoms, it was uncertain whether he had been bitten by a mosquito in Thailand or in Oman (Mohammad et al., 2008). The risk remains high in Oman because of environmental conditions, such as high temperature and high humidity, both of which allow mosquitoes to breed.

Another case study reported a Yemeni man living in the USA. The first documented case of dengue in Yemen was reported in 1984 (Saad et al., 2005). In 1983, a Yemeni man from the USA visited his home country of Yemen, and arrived back home in Detroit, Michigan, with symptoms of the dengue virus. He was found to have dengue and it was determined that he had probably been infected on a trip to Yemen (Jimenez-Lucho, Fisher, & Saravolatz, 1984).

Larger scale studies on a population level also provide evidence for transmission through travel. Despite Kuwait being a small, dry, and non-endemic country many Kuwaitis travel to areas where dengue is endemic (Mustafa et al., 2001). In addition, a number of expatriates come to Kuwait to work, the prevalence of people who have travelled outside Kuwait and then re-entered the country is relatively high, bringing an increased risk of dengue transmission (Mustafa et al., 2001). Mustafa et al. (2001)

conducted a study that reported on 210 patients, with dengue-like symptoms, who were admitted to the Infectious Disease Hospital in Kuwait during 1997 to 1999. Nine percent of patients had in fact been infected with a dengue fever virus (Mustafa et al., 2001). Some were Kuwaitis who had travelled to Thailand, the Philippines, and Saudi Arabia, whereas some were non-Kuwaitis who travelled regularly and who had returned from countries which are known to have dengue fever virus endemic areas, such as India, Sri Lanka and Kenya. The results of this study reported a high prevalence of dengue fever virus antibodies in both the non-Kuwaitis and also the Kuwaitis who had visited dengue-endemic countries (Mustafa et al., 2001).

Travel to mass events

In Brazil, there was significant preparation prior to the 2014 Football World Cup to determine the risk of dengue fever for cities where matches were to be played (Lowe et al., 2014). Real time seasonal climate forecasts were compiled to predict risk. Risk alerts and thresholds were identified which allowed the Ministry of Health and local authorities to implement control actions before the World Cup games (Lowe et al., 2014). In Saudi Arabia, more than four million pilgrims coming from different parts of the world visit Makkah, considered to be the holiest city, to perform Hajj or Umrah (a pilgrimage). Because of this Makkah has epidemiological significance for infectious diseases and as a consequence the city has continued surveillance and implemented vector control programmes to detect any changes in outbreaks of dengue fever (Khan et al., 2008).

2.4.3 Urbanisation and population

Urbanisation is a major force that has contributed to the increased number of dengue fever cases and of dengue epidemics (D Gubler, 2011). Growth in urban areas has made it possible for large densities of *Ae. aegypti* to thrive among crowded human populations, particularly in tropical cities, making it an ideal environment for dengue epidemics to occur (D Gubler, 2011). Because the *Ae. aegypti* vector adapts well to urban environments, it can be found among man made containers such as tyres that have been lying around as well as plastic receptacles that have been neglectfully discarded (DJ. Gubler, 1997b; D Gubler, 2011).

Rapid urbanisation and development is a matter of concern in relation to dengue fever around the world. This concern is for two main reasons: cities create environmental conditions which may be hospitable to the *Aedes* mosquito, and because other aspects of urbanisation such as migration and population mobility can help to spread dengue fever.

In Asia, after the Second World War, many cities such as Bangkok, Manila, and Jakarta experienced an economic boom as well as a significant increase in populations. As a result, many people moved to the cities, living in poor conditions with below average housing, little or no water, sewer or waste management services. The combination of all these factors created optimal conditions for dengue transmission. This was the type of setting where the first epidemic of dengue haemorrhagic fever appeared (D Gubler, 2011).

The shortage of water in many urban areas makes it necessary for people to store water in large containers and this has contributed to the increased mosquito population (DJ. Gubler, 1997b). One interesting case is the urbanisation of dengue fever in Brazil. There had been no reported cases of dengue in Brazil between 1923 and 1982 (Roberto, 2011) but the situation changed in the 1980s during Brazil's urbanisation when there was a lack of water and garbage services. These conditions helped create favourable environmental conditions that were conducive to *Ae. aegypti* breeding (Roberto, 2011). Furthermore, other factors aided in transmitting the dengue virus such as the highly crowded public transportation system, migration, and commuting of people. In places where there are high levels of migration and mobility there is the concern that the dengue virus may spread and become an epidemic (Roberto, 2011).

The population density of a community can also be a determinant for dengue fever. It is thought that having a high human population density, accompanied by an inadequate water supply contributes greatly to dengue epidemics and rural areas with a low population have also been found to have severe epidemics; however, there is little data to support these assumptions. In a study in Vietnam, space-time statistics and spatial analysis were used to identify a range of human population densities between 3,000 to 7,000 people per kilometre which were prone to dengue fever outbreaks. It is also possible that dengue virus transmission can occur in low population densities when there is a high mosquito to human host ratio and a lack of tap water supply (Schmidt et al., 2011). Dengue fever was more prevalent in rural areas of Thailand than in urban regions but this does not mean that urban centres do not make a significant contribution to the spread of dengue (Chareonsook, Foy, Teeraratkul, & Silarug, 1999). The ratio of vector to host may just be less appropriate for acute transmission, but the numbers of cases can still be high (Schmidt et al., 2011).

Indications from Yemen suggest that stagnant water, open sewers and standing water are contributors to the persistence of dengue fever. Prior to 2006, no cases of dengue had been reported in Yemen since 1997 (WHO, 2002b). In 2005, there were 945 cases, while in 2006 the number dramatically declined to 113 cases (Ministry of Public Health & Population, 2006) then in 2008, there was a new outbreak in the hot month of May (IRIN, 2008). It was thought likely that the primary cause in that year was the amount of stagnant water present around people's residences (IRIN, 2008). The rains also played a role in spreading the disease because it would accumulate in uncovered storage jars, although people were advised to remove any stagnant water. *Ae. aegypti* was the main vector found to have caused the outbreaks (IRIN, 2008).

Dengue continues to persist in Yemen, with hundreds of people in Taiz City reported with dengue fever and the hospitals receiving many patients every day (IRIN, 2009). Unfortunately, Taiz is a fertile environment for mosquitoes to breed with many uncovered tanks, especially in the poorer areas of the city. Open sewers and standing water contribute to the vector's reproduction. Dengue is not yet considered an epidemic in Taiz; however, it reappears where there is standing water and pollution (IRIN, 2009).

2.4.4 Cultural and lifestyle factors

Culture and lifestyle may contribute to the occurrence of dengue fever. It has been suggested that environmental and economic factors such as the financial ability to use air conditioners and human behaviour can have an effect on reducing contact with the *Ae. aegypti* mosquitoes (Paul Reiter et al., 2003). A study by Reiter et al. (2003) compared the cities Nuevo Laredo, Mexico to Laredo, Texas, USA and how the environment affected the transmission of dengue fever. Both cities have warm weather conditions but in Nuevo Laredo, the buildings often lacked air conditioning and doors and windows were open allowing the *Ae. aegypti* to enter and have contact with people. In Laredo, Texas, the use of air conditioning was prevalent and windows and doors were sealed; therefore, there was less of a chance for *Ae. aegypti* and humans to come into contact. In terms of economics, the cost of electricity was the same between the two cities; however, the families in Laredo, Texas could afford it more easily because incomes were higher. As a result, both economics and environmental factors played a role reducing the possibility of dengue transmission (Paul Reiter et al., 2003).

Socioeconomic status may have an influence on the amount of knowledge the people have regarding dengue fever. A study in Pakistan, where the number of dengue cases had increased during 2005-2006 (Syed et al., 2010) measured the knowledge, attitudes and practices regarding dengue fever of adults from high and low socioeconomic groups. The results from questionnaires revealed that the majority of respondents from both rich and poor backgrounds had heard about dengue disease: 96.5 % from high socioeconomic backgrounds and 88% from low socioeconomic groups. Only about a half of them knew the vector was the *Aedes* mosquito. In terms of knowing about the water requirement for the breeding of the dengue vector, 36% from the high socioeconomic group and 21% from the low socioeconomic group were aware that the mosquito breeds in fresh standing water; thus while most of the respondents had heard about dengue, only 35% had adequate knowledge. Among respondents with the highest levels of knowledge about dengue, 68% were from the high socioeconomic group: in contrast only 32% who had a high level of knowledge were from low socioeconomic groups. People from the high socioeconomic group also had more knowledge of preventive practices and undertook these practices compared with the poorer group. Resources in education about dengue should be spread more equally in the high and low socioeconomic neighbourhoods (Syed et al., 2010).

Studies in Rajasthan and Jodhpur, (2006), India reported on the relationship between three socioeconomic levels and the actual distribution of *Aedes* mosquitoes. This study demonstrated that the relationship between socioeconomic status and dengue practice is complex and needs to take cultural factors into account. Seven neighbourhoods were surveyed in late 2003. Some of the areas consisted of orchards and cattle sheds outside the city, low socioeconomic level areas in low and high altitude regions and high socioeconomic levels outside and inside the city. It was determined that domestic containers primarily used for animals for religious purposes provided the breeding grounds for most of the *Aedes* mosquitoes. These were typically located in the inner city among people who were highly educated but also highly religious. These religious beliefs made the neighbourhood more susceptible to the risk of dengue transmission. The lifestyle of the citizens influenced by their socioeconomic status and neighbourhood had a significant impact on determining the abundance of dengue vectors in urban Rajasthan (Joshi et al., 2006).

Culture can be a primary reason for males having more dengue fever cases than females in Saudi Arabia and Jeddah City. In Saudi Arabia, culture dictates under Islamic law that women have certain restrictions which include forbidding them to drive or work far from their homes or families. This may have an impact on a woman’s exposure to any disease such as dengue fever. Males, on the other hand, are allowed to travel and work wherever necessary, exposing themselves to the dangers of contracting dengue (Mobaraki & Söderfeldt, 2010).

Because men are the main income earners, it has been suggested that Saudi men may get sick more than women. One reason for this is because of men’s gendered roles, customs and identities. Women tend to pay more attention to their own health because they believe that if they become ill, their husbands may take a second wife. Furthermore, a man’s role takes him outside the home and exposes him to different environments making him more vulnerable to health risks such as dengue fever (Alyaemni, Theobald, Faragher, Jehan, & Tolhurst, 2013).

2.4.5 Neighbourhoods and socioeconomic factors

There has been much interest in geographical or place effects and their influence on health (Kawachi & Berkman, 2003). Research has found many neighbourhood characteristics that have an influence on health outcomes and health behaviour. While individual attributes such as age, gender, and ethnicity are important, so too is the independent influence of different neighbourhood factors on the health and well-being of inhabitants (Kawachi & Berkman, 2003; Stevenson, Pearce, Blakely, Ivory, & Witten, 2009). Three types of neighbourhood characteristics have been identified which may be important for residents’ health: physical factors (such as air pollution), sociocultural variables, and access to community resources (Stevenson et al., 2009).

Policy interventions conducted at the area level differ widely by type and scale. While people's perceptions of their neighbourhood environments have been important in explaining health behaviours and outcomes (e.g. Ellaway et al., 2001; Slopen et al., 2013), indirect measures, using census data, have been used to investigate neighbourhood features that potentially affect health outcomes or use of health services. For example in New Zealand, the New Zealand Deprivation Index has been used to obtain neighbourhood characteristics and it has been found that more deprived neighbourhoods have higher hospital admission rates and poorer health outcomes than those areas that rate as “less deprived” on the Index (J. Pearce, Barnett, & Jones, 2007). Even though understanding these findings can be problematic, it provides a tool to draw attention to health inadequacies and potential risks in neighbourhoods (Stevenson et al., 2009).

Overall, drawing a connection between neighbourhood characteristics to health status is important because it provides an opportunity to assess the importance of various contextual effects on health-related behaviours and health outcomes. This wider literature on neighbourhoods and health also helps in developing a greater understanding of the processes which lead to neighbourhood differences in rates of dengue fever; however, to date there have been few studies that have explored such links.

Developed countries have also experienced a relationship between *Ae. aegypti* mosquitoes and socioeconomic status. A study on high levels of mosquitoes in low income neighbourhoods of Baltimore and Washington DC, in the USA, focused on the ecological and social factors where mosquito populations increase in economically varied neighbourhoods. High, medium and low socioeconomic neighbourhoods were examined, and various breeds of mosquitoes were sampled from each location. It was found that the *Aedes* pupae were more likely to be found in the lowest income neighbourhoods. The species of mosquito and their abundance varied with the economic conditions. One explanation may be that government efforts in mosquito control may vary according to city-level differences. The number of discarded tyres was also a significant predictor of *Aedes* production as well as the presence of planters and other containers (LaDeau, Leisnham, Biehler, & Bodner, 2013).

There has been only one study conducted in the Middle East which centred around dengue fever and socioeconomic variables (Khormi & Kumar, 2011). This study attempted to assess the risk of dengue fever based on spatial relationship and socioeconomic levels in Jeddah. Socioeconomic factors such as population numbers, population density and neighbourhood quality were examined. In this study the use of spatial information improved the understanding between socioeconomic factors and dengue incidence. The results showed that areas at risk ranged from low to high, based on population, population density, and quality of the neighbourhood to dengue fever within the case study time period (Khormi & Kumar, 2011).

Khormi and Kumar's study determined that the quality of the neighbourhood can be a good indicator for predicting areas that are at high risk for dengue. Neighbourhood quality was assessed through high resolution satellite images based on factors such as the number of houses in each neighbourhood in each district, width of streets, and roof area of houses. The study showed that areas at high risk for dengue had 71% low neighbourhood quality; medium quality neighbourhoods were at 21% risk, and high quality areas were at 7% risk. The lower the quality of the neighbourhood was, the higher the risk of dengue. In old Jeddah districts, there was a spatial clustering of neighbourhoods with low quality that was associated with high risk, but some of the areas of medium risk only had 35% of low neighbourhood quality, while some of the high quality neighbourhoods had a risk factor of 43%. The distribution of areas with the lowest risk of developing dengue was 70% high neighbourhood quality, 2% medium quality and 28% low quality. Moreover, areas that had a low risk of dengue were predominantly Saudi residential areas (65%), while areas of high risk were more likely (53%) to contain non-Saudi populations. Low risk districts also had high neighbourhood quality and low population densities (Khormi & Kumar, 2011).

There are a number of possible pathways by which neighbourhood socioeconomic status has an effect upon dengue (Figure 2.5). The first pathway is observed through the neighbourhood population densities in the low socioeconomic status neighbourhoods that influence dengue fever cases. Areas with a high population density are more likely to have a higher number of dengue fever cases in the neighbourhoods with low socioeconomic status because the *Ae. aegypti* mosquito has a greater chance of transmitting dengue fever rapidly between the people. Moreover, the *Ae. aegypti* mosquito can usually be found around poorer environments which are located in the low socioeconomic status neighbourhoods.

The second pathway is the presence of migrant people who reside in low socioeconomic status neighbourhoods as this may also influence dengue fever cases. Migrant people can bring dengue fever and the *Ae. aegypti* mosquito with them especially those who come from dengue infected countries. Low socioeconomic status neighbourhoods can provide a suitable place for migrants to live because of cheap housing and the ability to create their own lifestyle away from the local people. Moreover, these neighbourhoods provide a kind of safe harbour for illegal immigrants because it is difficult for the Government to find them there.

The third pathway centres around the role of cultural and lifestyle factors that may be characteristic of low income neighbourhoods. Cultural factors may operate in a variety of ways. First, cultures of poverty, which emphasise a lack of future orientation may result in fatalistic attitudes to health issues including dengue. Second, lack of material resources may also be important as low income residents are unable to afford quality housing, including the provision of air conditioning, which will help limit the entry indoors of dengue carrying mosquitoes. Third, migrant people, with their own distinctive cultures, may be distrustful of Saudi health authorities and thus be uncooperative with respect to local prevention programmes.

Of course, Saudi culture itself by restricting the ability of females to work and travel outside their homes will result in complex interactions occurring between gender and socioeconomic status. It is possible that higher income Saudi and non-Saudi women, because they are more likely to break with tradition by being more active outside the home, will be less exposed to dengue than lower income women. Thus we might expect that the lessening of cultural constraints among higher income women will result in greater gender gaps in the incidence of dengue, especially in lower income neighbourhoods where women are more confined to poorer housing.

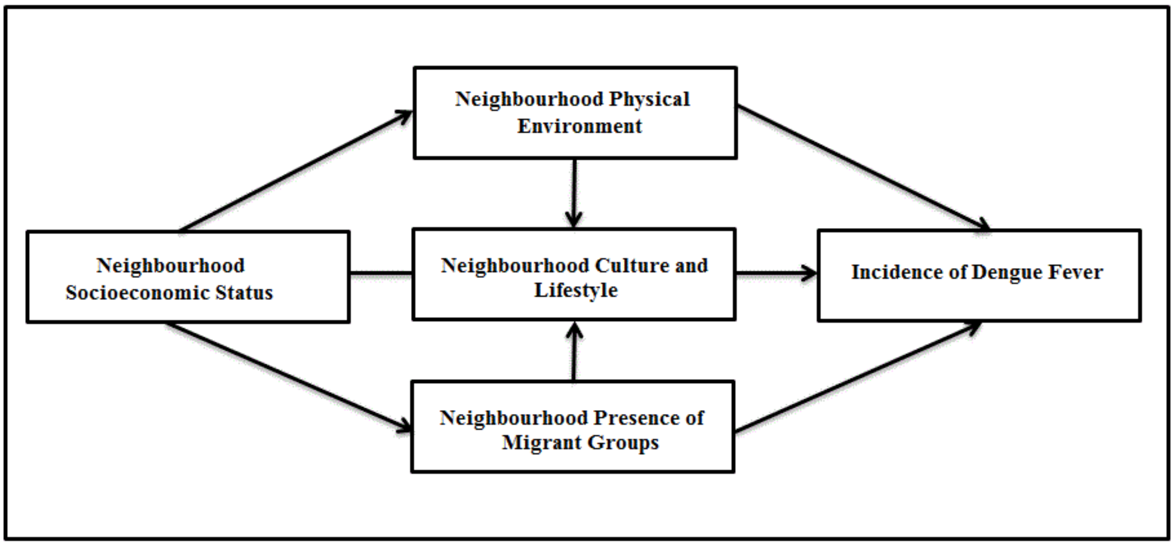

Figure 2.5 Dengue fever explanatory factors pathways

2.5 Dengue control: Problem of policy development and implementation

When considering public policy and its implementation it is important to use a conceptual framework to help guide research and interpret findings. Some frameworks are complex and relevant to well-developed policy systems, and also rely on a high level of research capability for their application (Brindis & Moore, 2014; Shediac-Rizkallah & Bone, 1998). In a country such as Saudi Arabia, however, the policy system has historically not been transparent and there has been limited research into policy and implementation (Al-Sobhi, Weerakkody, & Kamal, 2010; Zamani - Farahani & Henderson, 2010).

In developing an approach to dengue fever policy and implementation, it is essential to adopt a simple framework that will allow an initial investigation in this un-researched field. Policy-making and implementation is often described as being either top-down or bottom-up. Top down involves centrally controlled decision-making and implementation direction from those who are in an authoritative position. This approach, can be effective because the decision makers are responsible for devising an efficient statute or programme as a solution to an existing problem (Matland, 1995). Bottom up relies on community, local, decentralised or contracted agencies to develop and deliver the programmes (Brodkin, 1990).

The WHO Global Strategy for Dengue Prevention and Control for 1995 and 2012-2020 includes both approaches. It strongly promotes organised approaches to surveillance and mosquito control (p.14) (WHO, 2012), but also notes that the community plays a vital part in the dengue fever controls which helps to lower the risk of dengue fever cases (p.15) (WHO, 2012).

The top-down approach may not always be the best solution. Some countries have found that an over-reliance on insecticide programmes to target adult mosquitoes has not always been successful (WHO, 2012). It became necessary for this approach to be re-evaluated and to consider a more bottom-up approach that involves the community, and a number of studies have investigated the community contribution to dengue control (Ávila Montes et al., 2004; Espinoza-Gómez et al., 2002; Fernandez et al., 1998; Kay et al., 2002;

Lardeux et al., 2002; Leontsini et al., 1993; Nam et al., 2005; Raju, 2003; Sanchez et al., 2005; W Swaddiwudhipong et al., 1992; Wang et al., 2000).

Many strategies called for the use of community based approaches for *Ae. aegypti* control as represented in a bottom-up approach. It is essential that populations with dengue fever epidemics use strategies that involve educating citizens and making them aware of the dengue virus in order to reduce and control dengue fever. A combination of these approaches should deliver short term, as well as long term, success (D. J. Gubler & Clark, 1996).

The bottom-up approach involves more community, education, and dengue fever control, and there are examples of successful programmes in some parts of the world. For example as seen in a study in Southern Thailand, the community attempted to take action to control dengue. A school in Southern Thailand worked on capacity building and training. One school set up groups with the intention of developing a community-based approach to capacity building, preventing dengue and measuring control outcomes. Even though the school successfully increased student capacity, it was found that there may still have been a high risk for a dengue epidemic because of the high ratios of larval indices. Communities, therefore, need to look closely and understand the type of capacity building and training that is required to support dengue fever prevention and control (Suwanbamrung et al., 2012).

Despite the bottom-up approach being successful in some areas, weaknesses do exist. This kind of approach may risk putting too much responsibility onto unsupported communities. Even though the Thailand project was successful, it was not enough. It needed more support in the top-down technical areas to decrease the larval indices. In a comparative study of dengue control in Martinique and French Guyana, there was a change in responsibility from public authorities to the private sector. The local community strongly demanded mosquito control and called for the involvement of public officials. While there was increased community awareness, this did not necessarily lead to better control. Officials needed to support their efforts more and focus on preventing dengue fever while maintaining a close relationship with the population (Mieulet & Claeys, 2014).

Sometimes top-down and bottom-up are described as “irreconcilable” ends of an intervention model (Crescenzi & Rodríguez-Pose, 2011), but in fact there is ample evidence that many policy and implementation situations reflect a combination of both approaches and that these can be considered complementary. One such example can be seen in Singapore. The *Ae. aegypti* control programme in Singapore has experienced variable success and sustainability. During a dengue haemorrhagic fever epidemic in the 1960s the Destruction of Disease-Bearing Insects Act was implemented. It placed emphasis on reducing the source of dengue and enhancing community education. After it was made illegal to harbour larval habitats for *Ae. aegypti* mosquitoes, over 1,500 Government inspectors acted as health educators and law enforcement officers, and citizens were issued fines which resulted in significant income for health education and vector control (Chan, Chang, Laird, & Phanthumachinda, 1990). This strong top-down method proved to be successful for some years; however, in 1996, Singapore experienced a resurgence of dengue fever and dengue haemorrhagic fever even though the mosquito population had remained low (D. J. Gubler & Clark, 1996). In this example, it demonstrated the sustainability of a top-down policy, without complementary bottom up elements (Crescenzi & Rodríguez-Pose, 2011).

Puerto Rico used a bottom-up approach involving comprehensive community based *Ae. aegypti* control programmes. Their control strategy had five basic elements: surveillance; professional education; emergency hospital contingency plans; vector control; and community-based, integrated *Ae. aegypti* control. According to research by Gubler and Velez, (1991), surveillance and education had been the most successful of these approaches; however, there have been problems in the development and implementation of the other three strategies (D. J. Gubler, 1989; D. J. Gubler & Casta Vélez, 1991). There was a significant effort to educate citizens and encourage them to take community ownership of the programme. Non-government sources financially supported the programme. Mass media was also successful in disseminating awareness and convincing the population that dengue could be controlled. In 1994, despite these efforts, Puerto Rico had the worst epidemic of dengue, and it was necessary to review efforts to control it. Despite the early detection of dengue, the high level of awareness about dengue prevention by the community was not used as a foundation to organise the public to action (D. J. Gubler & Clark, 1996) and therefore, more top-down support was probably needed to ensure that this took place

Education from a bottom-up perspective has proven successful in many parts of the world in helping control the dengue virus (Joshi et al., 2006; Khun & Manderson, 2007;

Madeira, Macharelli, Pedras, & Delfino, 2002; Syed et al., 2010). One example from Brazil involves teaching primary school children about dengue fever and dengue control. Their knowledge of dengue was assessed at different times in their lessons. The group of students, who received education, when compared with a group that did not, had higher scores on questions concerning control measures. These students showed a heightened interest in the subject and adopted attitudes to prevent the *Aedes* mosquito. This study suggests that inserting a dengue module into the curriculum can effectively instruct students about dengue and that it can be controlled using simple measures (Madeira et al., 2002). An integrated approach to health policy is present in Brazil, with many improvements in health attributed to a comprehensive national health system that requires much social involvement. This is not easy to sustain and administering a decentralised public health system that involves the private sector causes some conflict and inconsistency (Victora et al., 2011).

Similarly, in Cambodia, health education is seen as vital for dengue control. While it is desirable that all community members are fully aware of the dengue mechanisms and the main activities that can prevent and reduce dengue transmission, children are the main targets to receive this kind of education through television and radio, printed materials and health education materials. This is provided by activities and campaigns of the National Dengue Control Programme, but unfortunately this programme appears to be funded only on an irregular basis. As a result, compliance is only partial. There is, therefore, a strong need for a more sustainable and affordable programme to prevent and control dengue in Cambodia (Khun & Manderson, 2007). In this example, the bottom-up approach worked well at the local level; however but due to irregular funding it was not sustained. Top-down support may have enabled it to be more effective.

It is clear from this short review that is it likely that a combination of top-down and bottom-up policy components are required. Saudi Arabia is an authoritarian state that lends itself to top-down policy and implementation and it is unclear to what extent community level engagement is complementing dengue control strategies. Indeed, it is unclear exactly how the dengue control policy is developed and implemented and further investigation is required.

2.6 Literature overview and approach to the research

There have been many studies that have examined the relationship between dengue fever and a range of variables. Here an overview of earlier research on dengue fever indicates research gaps in dengue fever control and a research context that informs the particular objectives of this thesis.

Many criticisms can be made of previous studies on dengue fever both in Saudi Arabia and more broadly. First, most of the studies which have considered aspects of the local environment have focused on the effects of climate variations on dengue fever; however, there has been no research which has attempted to evaluate the combined impact of physical and social features upon the incidence of dengue. This omission is surprising given the bourgeoning research on neighbourhoods and health that has occurred in the last decade which has focused on the impact of local environmental factors on both infectious and lifestyle diseases (Joshi et al., 2006; Paul Reiter et al., 2003; Syed et al., 2010). Neighbourhood factors such as population density, neighbourhood social status or ethnic composition have received little attention despite their relationship to well documented health inequalities in western countries. Nor has much attention been paid to the interaction of social and environmental factors upon the incidence of dengue, a well-worn theme in environmental justice research in western contexts (Hagenlocher, Delmelle, Casas, & Kienberger, 2013; Kawachi & Berkman, 2003; J. Pearce, Day, & Witten, 2008; J. Pearce, Witten, Hiscock, & Blakely, 2007; Stevenson et al., 2009).

There has been a dearth of studies about dengue fever connected with the socioeconomic level of the neighbourhoods in the Middle East. Only one study was found by Khormi and Kumar, (2011) about dengue fever in Jeddah City neighbourhoods; however, the measure used to establish the socioeconomic level was limited in that it only took account of the width of the street, house density, and roof area of houses, and did not include the characteristics of the people living there or any measure of socioeconomic level (Khormi & Kumar, 2011).

While the relationship between climate variables and dengue fever has received some attention, most researchers focused on global patterns or centred on countries with a typical tropical climate. Middle Eastern countries do not have a tropical climate but rather they have a dry climate with a low level of rainfall. This is important because *Ae. aegypti* mosquitoes can exhibit different behaviours when living in dry climate conditions.

Most international climate studies have also used monthly and yearly data to analyse and model dengue fever cases (Nagao et al., 2003; Promprou et al., 2005; Wu, Guo, Lung, Lin, & Su, 2007). For example, in Jeddah City, one study used monthly data on temperature and humidity to demonstrate that higher temperatures and lower humidity lead to higher mosquito densities across the city as a whole and consequently higher rates of dengue fever (Alshehri & Saeed, 2013), but no attempt was made to examine local neighbourhood variations in dengue rates. No studies have used a more detailed time frame to model weekly variations in dengue cases and how these may vary by neighbourhood type. Such analyses are important to gain a greater appreciation of local hotspots and how the virus tends to spread out from these, as well as gaining an understanding of the types of neighbourhoods where peak outbreaks of dengue fever are most likely to occur. The time lag between weather sequences of dengue fever needs to be better understood. While a study in Taiwan, (Wu et al., 2007) used a monthly time lag for the temperature and rainfall to predict the incidence of dengue, it did not take account of local variations and patterns of spread. More detailed temporal and spatial analysis is thus necessary in order to better understand the lag effect.

Global travel and migration studies showed that people's movements can be a reason for the spread of dengue fever around the world (Antinori et al., 2004; Bulugahapitiya et al., 2007; M. E. Wilson, 2003). Every year millions of pilgrims go to Makkah City through Jeddah's airport, but there have been no studies investigating the relationship between dengue fever cases and travel to Jeddah City.

There are few studies in the Middle East of dengue fever, and most of these discussed the surveillance of cases (Khormi, Kumar, & Elzahrany, 2011) and travel factors (Mohammad et al., 2008; Mustafa et al., 2001). In Saudi Arabia there are special factors due to local culture and location which can affect dengue fever in a different way to other regions. No study has considered Saudi culture and lifestyle as a contributing variable to dengue fever persistence or control. Although there have been a number of studies on control strategies for dengue fever (D. J. Gubler & Clark, 1996; Hwang, Wang, Chen, Roam, & Chow, 1992; Khun & Manderson, 2007), no studies in the Middle East have examined dengue control strategies, and no qualitative studies have been used to try to understand the concepts and practices of dengue fever control.

2.7 Conclusion

This chapter has provided the background to how dengue fever is transmitted by the female *Aedes* and the similarities and differences between dengue fever and dengue haemorrhagic fever. Dengue has two vectors: *Ae. aegypti* and *Ae. albopictus*. The vector *Ae. aegypti* is widespread in tropical and subtropical areas, while the *Ae. albopictus* can be found in tropical and temperate Asian countries. A number of factors which have an impact on the transmission of dengue fever were outlined.

Climate variables and climate change, increased travel and migration, urbanisation and population and education and community awareness have all played a role in the global appearance of dengue. Each of these factors was examined and the various studies showed the relationship between dengue fever and its causes. The importance of climate variables and the implications of climate change was highlighted. The section on dengue and global travel and migration factors noted that travellers and migration increase the risk of distribution of dengue when returning home from dengue infected areas. The discussion of urbanisation and population found that the conditions of the urban areas can contribute to the large densities of *Aedes*, putting all the people living there at risk. The last factor involves education and awareness of the community which shows the importance for people to have knowledge about dengue fever to protect themselves.

It is evident that low socioeconomic neighbourhoods have more dengue fever cases than high socioeconomic neighbourhoods and that there may be a number of different pathways for the impact socioeconomic factors on dengue fever cases.

Examples were given regarding different countries' approaches to educate its population about dengue. Finally, the critique of dengue fever studies found few studies of dengue fever in the Middle East or Jeddah City. In particular studies that assessed dengue fever factors and the control strategies within a single study framework were absent.

The next chapter presents details of the distribution of dengue fever in Saudi Arabia, and particularly the situation in Jeddah City. The Saudi Arabian Government's Control Strategies for dengue fever in Jeddah are discussed.

Chapter 3: Dengue Fever in Saudi Arabia and Government Strategies for Control

3.1 Introduction

The purpose of this chapter is to provide a geographical context for the study of dengue fever in Saudi Arabia, a country where there are a number of cities where the population has been infected with the disease, and to understand the Control Strategies for dengue fever in the priority city of Jeddah.

The chapter is divided into six main sections. Section 3.2 describes the national and regional setting for the study. Section 3.3 discusses dengue fever in Saudi Arabia as a whole and its regions, including the Makkah region which has the most dengue cases. Section 3.4 explores dengue fever across the Makkah region and identifies Jeddah as the most affected city. Section 3.5 discusses the patterns of dengue fever in Jeddah City itself. Section 3.6 examines the Saudi Arabian Government's Control Strategies for dengue fever in Jeddah City. Section 3.7 provides a concluding discussion for the chapter.

3.2 The study setting: the Kingdom of Saudi Arabia

The Kingdom of Saudi Arabia is located in the most south-western part of Asia. It covers about four fifths of the Arabian Peninsula and comprises a total land area of 2,000,000 square kilometres. The Kingdom is divided into 13 administrative regions by a Royal Order (No. 1/92, 2 March 1992). Each region is divided into a number of governorates (cities). Each governorate further consists of centres linked administratively to the governorate itself, or to the emirate (county). A number of population settlements are connected administratively to the emirate, governorate or the centre (Central Department of Statistics & Information, 2010).

3.2.1 The climate of Saudi Arabia

The diverse topography of Saudi Arabia means that the country's climate is quite variable from region to region. As a result of frequent subtropical high pressure systems, the Kingdom is normally hot in the summer and cooler and wetter in the winter (Central

Department of Statistics & Information, 2010). Primarily, the country has desert weather conditions, which consist of extreme heat during the day with a sudden temperature drop at night, and very little rainfall. The subtropical high pressure systems result in much variation in temperature and humidity, and these differences can be felt between the coastal areas and the interior. The average temperature in the summer is about 45 ºC, but it can reach even higher: up to 54 ºC. In the winter, the temperature hardly ever goes below 0 ºC, however the lack of humidity and the high wind-chill factor can make it quite cold. Furthermore, because of the high winds that occur at this time of year, it is common to see powerful sand and dust storms. Near the coastal lands by the Red Sea and the Arabian Gulf, strong sand storms and dust storms also occur during the spring and summer. Temperatures in spring and autumn are around 29 ºC.

Between the months of October and March, an average of 300 millimetres of rain fall, about 60% of the annual precipitation, occurs along the western coast. At other times of the year, rainfall is very low and erratic; there may be only one or two heavy rainstorms or thunderstorms per year.

Because of the subtropical climate conditions in Saudi Arabia, dengue fever can be found in those areas that have a high humidity and temperature suited to increased breeding of the *Aedes* mosquito. In addition, because urban environmental changes are creating new breeding sites for mosquitoes the risk of contracting dengue has increased (Biittiker, 1981). This will be discussed further in the next chapter.

3.2.2 Regional structure and population

An understanding of the regional structure of Saudi Arabia is important because dengue fever is highly localised and its control largely a regional responsibility. Figure 3.1 shows the 13 regions of Saudi Arabia. The largest region in the area is the Eastern region, followed by Al-Riyadh region, in which the capital city is located. The smallest regions are Al-Baha and Jazan. Table 3.1 shows the number of governorates in each of Saudi Arabia’s regions. The Al-Riyadh region has more governorates (19) than any of the other regions, followed by Jazan with 13. As demonstrated in Figure 3.1 and Table 3.1, the Al Jouf and Northern Borders regions each contain only two governorates and both are located in the most northern area of Saudi Arabia (Central Department of Statistics & Information, 2004). Table 3.1 also shows the preliminary results of the census in 2010. Approximately

65.6% of Saudi Arabia’s population lives in the Makkah and Al-Riyadh and Eastern regions. The least populated area is the Northern Border region with only 1.2% (Central Department of Statistics & Information, 2011).

Figure 3.1 Saudi Arabia regions

Source: (Central Department of Statistics & Information, 2011)

Table 3.1 Number of the governorates (cities) in Saudi Arabia regions and the preliminary results for Saudi Arabia regional Census, 2010

Region	Number of Governorates	Population (millions)	Percentage of total population
Al-Riyadh	19	6.7	25.0%
Makkah	11	6.9	25.5%
Al-Madinah	6	1.7	6.6%
Al-Qaseem	10	1.2	4.5%
Eastern Region	10	4.1	15.1%
Aseer	11	1.9	7.1%
Tabouk	5	0.79	2.9%
Hail	3	0.59	2.2%
Northern Borders	2	0.32	1.2%
Jazan	13	1.3	5.0%
Najran	7	0.50	1.9%
Al-Baha	6	0.41	1.5%
Al-Jouf	2	0.44	1.6%
Total	105	27.1	100%

Source: (Central Department of Statistics & Information, 2011)

Table 3.2 shows the regional populations according to gender and Saudi/non-Saudi nationality[1]. In most of the regions, males outnumber females by about 1%; this is not a significant difference. In a few of the smaller cities such as in the Aseer region, Hail region, and Al Baha region, females slightly outnumber males. The highest concentrations of non-Saudi people are in the Makkah (2.7 million) and Al-Riyadh regions (2.4 million). Among the non-Saudi population in these regions there are significantly more males than females because fewer non-Saudi women than men are recruited to work in Saudi Arabia.

[1] Non-Saudi people are defined by the Saudi government in the national census as those who do not have a Saudi national identity card and passport.

Table 3.2 Preliminary results for Saudi Arabia regional census for Saudi and non-Saudi people (millions), 2010

	Saudi			Non-Saudi		
Region	**Male**	**Female**	***Population**	**Male**	**Female**	****Population**
Al-Riyadh	2.2 (51.7%)	2.0 (48.3%)	4.2 (63.4%)	1.7 (71.1%)	0.717 (28.9%)	2.4 (36.6%)
Makkah	2.0 (50.7%)	2.0(49.3%)	4.1 (59.5%)	1.8 (65.3%)	0.970 (34.7%)	2.7 (40.5%)
Al-Madinah	0.635 (50.3%)	0.627 (49.7%)	1.2 (71.0%)	0.350 (68.0%)	0.164 (32.0%)	0.515 (29.0%)
Al-Qaseem	0.470 (50.7%)	0.458 (49.3%)	0.928 (76.4%)	0.223 (77.7%)	0.063 (22.3%)	0.287 (23.6%)
Eastern Region	1.4 (51.8%)	1.3 (48.2%)	2.8 (70.4%)	0.924 (76.1%)	0.289 (23.9%)	1.2 (29.6%)
Aseer	0.790 (49.7%)	0.800 (50.3%)	0.159 (83.1%)	0.248 (76.9%)	0.074 (23.1%)	0.322 (16.9%)
Tabouk	0.339 (51.3%)	0.321 (48.7%)	0.661 (83.5%)	0.099 (76.0%)	0.031 (24.0%)	0.130 (16.5%)
Hail	0.242 (49.7%)	0.244 (50.3%)	0.487 (81.6%)	0.084 (76.6%)	0.025 (23.4%)	0.109 (18.4%)
Northern Borders	0.134 (50.2%)	0.133 (49.8%)	0.268 (83.7%)	0.039 (75.6%)	0.012 (24.4%)	0.052 (16.3%)
Jazan	0.559 (50.7%)	0.545 (49.3%)	1.1 (81.0%)	0.176 (68.1%)	0.083 (31.9%)	0.260 (19.0%)
Najran	0.202 (50.4%)	0.199 (49.6%)	0.402 (79.6%)	0.075 (73.0%)	0.027 (27.0%)	0.103 (20.4%)
Al-Baha	0.169 (48.6%)	0.179 (51.4%)	0.348 (84.6%)	0.048 (77.2%)	0.014 (22.8%)	0.63 (15.4%)
Al-Jouf	0.177(50.8%)	0.171 (49.2%)	0.349 (79.3%)	0.071 (78.4%)	0.019 (21.6%)	0.090 (20.7%)
Total	9.5 (50.9%)	9.1 (49.1%)	18.7 (68.9%)	5.9 (70.4%)	2.4 (29.6%)	8.4 (31.1%)

Source: (Central Department of Statistics & Information, 2011)

*Proportion of the total population of the region that are Saudi nationals.

**Proportion of the total population of the region that are non-Saudi nationals.

3.2.3 National population and migration trends

Population change and migration are two factors which can influence the distribution of dengue fever in Saudi Arabia, by altering the density and composition of the population. The size of the population in Saudi Arabia is growing which can lead to rapid urban development and subsequent risks to health. In addition, non-Saudi migrants may carry diseases, such as dengue, from different regions around the world and spread it to Saudi Arabia. The rest of this section explores national trends in population and migration.

Table 3.3 Saudi Arabia population (millions), 1974–2011

Year	Saudi	Non-Saudi	Total population
1974	6.2 (88.7%)	0.8 (11.3%)	7.0
1992	12.3 (72.6%)	4.6 (27.4%)	16.9
2004	16.5 (72.9%)	6.1 (27.1%)	22.6
2010	18.7 (68.9%)	8.4 (31.1%)	27.1

Source: (Central Department of Statistics & Information, 2011)

As seen in Table 3.3, the population of Saudi Arabia more than tripled between 1974 and 2010. By 1992 it had grown substantially to 12.3 million people, with (72.6%) Saudi and 4.6 million (27.4%) non-Saudi. In 2004, the total population had grown again: to 22.6 million in total, with 16.5 million people (72.9%) who were Saudi nationals and 6.1 million non-Saudi people (27.1%). By 2010, the population had increased steadily to 27.1 million people in all, with Saudi nationals comprising 68.9% of the total population, and the non-Saudi population of 8.4 million rising to 31.1% (Central Department of Statistics & Information, 2011). Over the last 40 years the population of Saudi Arabia has increased by 300%; this is mainly driven by an increase in the non-Saudi population which has increased from about 0.8 million in 1974 to 8.4 million in 2010, a ten-fold increase, and their proportional representation also increased by 300%. In the 1970s and 1980s the population increase may have been because of rapid immigration but this appears to have stabilised since 1992, and since then an increase in the Saudi population has made a near equal contribution to total population growth. Because the birth rates have remained high in Saudi Arabia, the profile of the population is very young. This suggests that the population structure and composition may have a role to play with secular trends in public health issues such as changes in the incidence of dengue fever.

The population of Saudi Arabia, by gender, is set out in Table 3.4. At each time period there were more males than females and the male per 100 female ratio overall increased over time from 113.2 in 1974 to 132.4 males per 100 females in 2010 (Central Department of Statistics & Information, 2011). This trend was less evident for the population of Saudi nationals where the number of males and females remained almost equal in number according to the census data over the years between 1974 and 2010 (Table 3.5). The population was consistently about 50% to 51% male and 48% to 49% female. The male per 100 female ratios in the table show that in 1974 the ratio was 105.6 and in 2010 it was 103.8 indicating that the proportion of females has slightly increased. The increased proportion of males in the total population is largely due to a predominance of a non-Saudi male workforce that comes to Saudi Arabia for employment opportunities as shown in Table 3.6. Again, a big increase can be seen among the non-Saudi population between the years 1972 to 2010, over two thirds (69%) of which were male. Consequently, the males per 100 female ratio increased from 201.4 to 237.7 in 2010 (Central Department of Statistics & Information, 2011). Gender differences are investigated in more detail in a later section to understand how they are related to the dengue fever cases in Saudi Arabia.

Table 3.4 Saudi Arabia population (millions) by gender, 1974–2010

Year	Male	Female	Males per 100 Females
1974	3.7 (53.1%)	3.2 (46.9%)	113.2
1992	9.4 (55.9%)	7.4 (44.1%)	126.9
2004	12.5 (55.4%)	10.1 (44.6%)	124.1
2010	15.4 (57.0%)	11.6 (43.0 %)	132.4

Source: (Central Department of Statistics & Information, 2011)

Table 3.5 Saudi Arabia census results for Saudi people (millions) by gender, 1974–2010

Year	Saudi		
	Male	Female	Males per 100 Females
1974	3.1 (51.4%)	3.0 (48.6%)	105.6
1992	6.2 (50.5%)	6.0 (49.5%)	102.0
2004	8.2 (50.1%)	8.2 (49.9%)	100.6
2010	9.5 (50.9%)	9.1 (49.1%)	103.8

Source: (Central Department of Statistics & Information, 2011)

Table 3.6 Saudi Arabia census results for non-Saudi people (millions) by gender, 1974–2010

Year	Non-Saudi		
	Male	**Female**	**Males per 100 Females**
1974	0.5 (66.8%)	0.3 (33.2%)	201.4
1992	3.2 (70.4%)	1.3 (29.6%)	237.5
2004	4.2 (69.4%)	1.8 (30.6%)	227.0
2010	5.9 (70.4%)	2.4 (29.6%)	237.7

Source: (Central Department of Statistics & Information, 2011)

The Tourism Information and Research Centre in Saudi Arabia report on all non-Saudi people who visit the country. The last report published in 2006 showed that 8,620,463 people visited Saudi Arabia that year. The report presented information on the different nationalities, where they came from and the purpose of their visit (religion, holiday, visit family and friends, business, and other). Table 3.7 shows that most people who visited Saudi Arabia came for religious reasons (51.4%), followed by business reasons (18.6%), and the third reason was visits to see family and friends (13.4%). The number of people who came for religious purposes is high because every year millions of pilgrims from different nationalities visit Saudi Arabia for the Hajj pilgrimage to Makkah. The majority of people who visited Saudi Arabia in 2006 were from the Middle East (58.6%) with about (37.2%) of this group coming for religious purposes. The second highest source of visitors was from Southern Asia (20.3%), and similar to the Middle Easterners, over three quarters of this group (77.5%) came for religious purposes. The third largest group of people (7.4%) came from South East Asia and their main purpose was also for religious reasons (68%). Some of these visitors who came to Saudi Arabia migrated to the country, which contributes to the increase population and possibly contributes to the rise of dengue fever cases.

Table 3.7 Visitor nationality in Saudi Arabia by purpose in 2006

Nationality	Religious	Holiday and Shopping	Visit Family and Friends	Business	Others	Total
Middle East	1,877,154 (37.2%)	55,4941 (11.0%)	1,086,195 (21.5%)	778,963 (15.4%)	751,254 (14.9%)	5,048,507 (58.6%)
Southern Asia	135,5629 (77.5%)	2,212 (0.1%)	2,527 (0.1%)	349,892 (20.0%)	37,856 (2.2%)	1,748,116 (20.3%)
Eastern Asia	443,026 (65.3%)	-	810 (0.1%)	172,662 (25.4%)	62,458 (9.2%)	678,956 (7.9%)
Europe	315,247 (63.6%)	-	15,540 (3.1%)	163,858 (33.1%)	975 (0.2%)	495,620 (5.7%)
Africa	408,801 (76.4%)	8,482 (1.6%)	48,551 (9.1%)	59,465 (11.1%)	10,049 (1.9%)	535,348 (6.2%)
America	17,297 (18.8%)	-	3,180 (3.5%)	71,286 (77.7%)	-	91,763 (1.1%)
Oceania	15,349 (69.3%)	-	-	6,675 (30.1%)	129 (0.6%)	22,153 (0.3%)
Total	4,432,503 (51.4%)	565,635 (6.6%)	1,156,803 (13.4%)	1,602,801 (18.6%)	862,721 (10.0%)	8,620,463 (100%)

Source: (Tourism Information and Research, 2006)

3.3 Dengue fever in Saudi Arabia

3.3.1 The dengue virus in Saudi Arabia

A twelve year study of dengue viruses circulating among local Saudis showed that dengue fever is likely to have been distributed into Jeddah City by travel, either during Hajj, by Saudis travelling abroad, or by migrant labour (Zaki et al., 2008). Over the years dengue fever Viruses 1, 2 and 3 have been found circulating. Saudi Arabian isolates from 1994 and 2004 were scattered within the other major lineage in the cosmopolitan genotype. Dengue fever Virus 3 continued to circulate from 1997 to 2004 and possibly 2005. It seems that dengue fever Virus 1 appeared in Saudi Arabia on two occasions. In the first outbreak of 1994, both dengue fever Virus 1 and dengue fever Virus 2 co-circulated, starting in the summer, coinciding with the Hajj. The virus seemed to peak around the summer months of May to July, and then again in November, during the rainy season near the end of the year. It would also surface during wet winters into January. A different strain of dengue fever virus caused the outbreak in 2005 and 2006 from a genotype found in Asia. There has been no change in the genotypes of dengue fever Virus 2 and dengue fever Virus 3 circulating since 1994 and 1997 (Zaki et al., 2008).

3.3.2 National trends in the incidence of dengue fever

The Ministry of Health in Saudi Arabia has recorded the number of dengue fever cases in the health statistical yearbooks, beginning with data from 2004 (Ministry of Health, 2006, 2007, 2008, 2009). There are some limitations, however, with this data; the 2006 yearbook reports that there are no available data for the years 2002 and 2003, and the records for the number of cases from 2004 to 2005 do not contain details such as the gender and age of those afflicted (Ministry of Health, 2006).

Table 3.8 Dengue fever in Saudi Arabia 2004-2009

Year	Cases	Percentage of total cases 2004-2009
2004	343	4.9%
2005	406	5.8%
2006	1,544	21.9%
2007	490	7.0%
2008	913	13.0%
2009	3,350	47.5%
Total	7,046	100

Sources: (Ministry of Health, 2006, 2009)

Table 3.8 shows the incidence of dengue fever cases in Saudi Arabia for the period 2004 to 2009. In 2004, there were 343 recorded cases across the entire country. This number grew substantially over the next six years, and in 2009 there were 3,350 confirmed cases of the disease (Ministry of Health, 2006, 2009). Interestingly, between the years 2006 and 2007, there was a substantial decrease in confirmed cases: in 2006 there were 1,544 confirmed cases, while in 2007 the number had dropped to 490. From 2007 the number resumed its rise. The reason for this fluctuating trend between 2004 and 2009 is unknown, but it may be attributed to climate variation, population migration or environmental variables. (Ministry of Health, 2006, 2009).

Table 3.9 displays the incidence of dengue fever by gender and nationality (Saudi/non-Saudi). In 2006 the number of male Saudi who had dengue fever was twice as high as the number of females who had the disease (Ministry of Health, 2006). In 2009, there was an increase in dengue cases among both Saudis and non-Saudis. Among non-Saudis, 82.5% (1,199) of those diagnosed were males and only 17.5% (255) were females. In contrast, the Saudi data reflected a somewhat more even distribution of dengue between males and females, although with males still over-represented (63.5%) compared with 36.5% for females.

Table 3.9 Dengue fever and males and females in Saudi Arabia

Year	Saudi			Non-Saudi			Grand Total	Ratios Male: Female
	Male	Female	Total	Male	Female	Total		
2006	674 (65.8%)	351 (34.2%)	1,025 (66.4%)	298 (57.4%)	221 (42.6%)	519 (33.6%)	1,544 (24.5%)	1.69:1
2007	178 (57.2%)	133 (42.8%)	311 (63.5%)	127 (70.9%)	52 (29.1%)	179 (36.5%)	490 (7.8%)	1.65:1
2008	275 (68.4%)	127 (31.6%)	402 (44.0%)	401 (78.5%)	110 (21.5%)	511 (56.0%)	913 (14.5%)	2.85:1
2009	1,182 (62.3%)	714 (37.7%)	1,896 (56.6%)	1,199 (82.5%)	255 (17.5%)	1,454 (43.4%)	3,350 (53.2%)	2.46:1
Total	2,309 (63.5%)	1,325 (36.5%)	3,634 (57.7%)	2,025 (76.0%)	638 (24.0%)	2,663 (42.3%)	6,297 (100.0%)	2.18:1

Sources: (Ministry of Health, 2006, 2007, 2008, 2009)

It is important to understand the male and female differences in the rates of infection of dengue fever. There have been a few international studies conducted from the dengue epidemics in India and Singapore (Agarwal et al., 1999; Ray, Kumar, Kapoor, Dutta, & Batra, 1999). These studies found that there were nearly twice as many male patients as female (Agarwal et al., 1999; Ray et al., 1999). Lucknow (India) and Singapore both reported ratios of 1.9:1 male to female, and Delhi's ratio was 1: 0.57 (Agarwal et al., 1999; Ray et al., 1999). In another study in Delhi, an even higher ratio of 2.5:1 males to females was reported (Wali et al., 1999). Data from Malaysia showed a male majority among Indian and Malay infected patients (1.5:1); however the ratio was almost equal for those of Chinese origin (Shekhar & Huat, 1992). Studies in South America revealed that both sexes are equally affected (J. Rigau-Perez, Aayala-Lopez, Vorndam, & Clark, 2001; Vasconcelos et al., 1993) A male to female ratio of 0.65:1 was considered typical for South America (Morens, Rigau-Perez, & Lopez-Correa, 1986). In a rare result, Kaplan discovered a higher proportion of women to men in all of his Mexican samples ($p < 0.001$) (Kaplan, Eliason, & Moore, 1983).

Kabra et al's (1999) studies in Asia found dengue fever to be more prevalent in men than in women; however, more women had severe sickness (Kabra et al., 1999; Shekhar & Huat, 1992). Halstead had mentioned that, as early as in the 1970s, it was mostly males who contracted milder diseases while the women were fewer in number but they had more severe illness (S. Halstead, Nimmannitya, & Cohen, 1970). One reason for this greater severity may be the immune response in females (S. Halstead et al., 1970). Kaplan, in

Mexico, proposed that the timing of the survey interviews may have had some influence on the severity of the women’s illnesses (Kaplan et al., 1983), but Goh suggested that women had a lower incidence because they stayed at home more and were less exposed to infection (Goh, 1995).

Data reported from 2006 to 2009 for Saudi Arabia showed that more males were infected with dengue than females, consistent with international studies. Gender differences in infection rates were highest in 2008 when the male to female ratio peaked at 2.85:1. This ratio is higher than the ratios reported in international studies (Agarwal et al., 1999; Goh, 1995; S. Halstead et al., 1970; Ray et al., 1999; Wali et al., 1999). The reason for that could be, as Goh suggested, Saudi women are more likely to stay at home and thus it is men who are more at risk of getting dengue fever. On the other hand the cultural and lifestyle factors influence the women who are living in poor environmental housing conditions to be more susceptible to the exposure of the *Ae. Aegypti* mosquitoes which enter into the houses through open windows and spread dengue fever (Paul Reiter et al., 2003). Moreover, Saudi women are not generally and repeatedly exposed to open places. The way they wear clothes covers all the body which means that skin is not exposed.

In Saudi Arabia different age groups have been differentially affected by dengue fever as demonstrated in Table 3.10. In 2006 the age group with the highest incidence of dengue fever was 15 - 44 year olds, while new-borns were the least affected (Ministry of Health, 2006). In 2007 the overall numbers declined somewhat, although the largest age group was again 15 - 44 (Ministry of Health, 2007). The incidence in the 1 to 4 age group decreased substantially between 2006 and 2007: from 114 to 12 in 2007 (Ministry of Health, 2006, 2007). In 2009, the number of cases in the 15 - 44 age group dramatically increased: from 669 in 2008, to 2421, and had the highest rate of increase of all age groups. The total number of cases where the age was unknown was 28. Altogether, there were a total of 3,350 diagnosed dengue cases in 2009 (Ministry of Health, 2009).

In South East Asia dengue fever is typically known as a childhood disease (Guha-Sapir & Schimmer, 2005), but there is evidence that dengue haemorrhagic fever has been increasing in the older age groups since the 1980s in both Asia, generally, and in Latin America (Guha-Sapir & Schimmer, 2005). Early studies in Cuba (Guzman et al., 1990), and in Puerto Rico (J. G. Rigau-Pérez, Vorndam, & Clark, 2001), confirmed this and similar observations were made in Nicaragua and Brazil (Health, 2000; RSA, 2000).

While international studies show that all ages can be at risk from dengue fever, studies have shown the increasing age of dengue patients in Asia. Singapore data showed a shift in peak dengue deaths from paediatric ages in the mid-1970s, to adults in 1982, and in 1982, more than 50% of dengue patients who died were over the age of 15 (Goh, 1995). From 1990 to 1996, the highest morbidity rates occurred between the ages of 15 and 34 (Goh, 1995). Indonesia also showed an increase in the proportion of dengue within the young adults (Sumarmo, 1987). Adults comprised 82% of all cases in hospital in 2000 when Bangladesh had a dengue epidemic (Rahman et al., 2002). Most of these adults were between the ages of 18 and 33, and all deaths occurred in patients over five years old (J. Rigau-Perez et al., 2001). In Puerto Rico, data analysis showed that the 10 - 19 year age group had the highest incidence rate during an outbreak in 1994 and 1995 (J. Rigau-Perez et al., 2001).

Table 3.10 Dengue fever in Saudi Arabia by age group

Years	<1	1–4	5–14	15–44	45+	Unknown	Total
2006	7 (0.5%)	114 (7.4%)	340 (22.0%)	805 (52.1%)	278 (18.0%)	-	1,544 (24.5%)
2007	5 (1.0%)	12 (2.4%)	69 (14.1%)	329 (67.1%)	75 (15.3%)	-	490 (7.8%)
2008	2 (0.2%)	9 (1.0%)	72 (7.9%)	669 (73.3%)	161 (17.6%)	-	913 (14.5%)
2009	24 (0.7%)	37 (1.1%)	310 (9.3%)	2,421 (72.3%)	530 (15.8%)	28 (0.8%)	3,350 (53.2%)
Total	38 (0.6%)	172 (2.7%)	791 (12.6%)	4,224 (67.1%)	1,044 (16.6%)	28 (0.4%)	6,297 (100.0%)
Change 2006-2009	17 (77.4%)	-77 (24.5%)	-30 (47.7%)	1,616 (75.0%)	252 (65.6%)	-	1,806 (68.4%)

Sources: (Ministry of Health, 2006, 2007, 2008, 2009)

When compared to other countries, it appears that Saudi Arabia has a comparable age distribution of dengue as that shown in Bangladesh, Singapore and Indonesia. The age group from 15 - 44 are more likely to get dengue fever in Saudi Arabia, while the range group in Bangladesh is from 18 - 33 and in Singapore from 15 - 34. The differences in age group reporting across countries makes clear comparisons difficult but nevertheless these general conclusions can be drawn.

3.3.3 Regional distribution of dengue fever

As illustrated in Table 3.11, dengue fever cases are reported from only five of the thirteen regions in Saudi Arabia. One region (Makkah) has by far the largest number of cases, followed by Al-Madinah, and Jazan; these three are located in the southwest Saudi Arabia. Most of the cases (97.95%) were reported from only one region (Makkah) (Ministry of Health, 2006, 2007, 2008, 2009). Makkah region had 1,507 cases in 2006 and while the number of cases decreased over the next two years it dramatically increased again to 3,328 in 2009. For the period 2006 - 2009 Makkah region had an average of 1,540 cases while in Jazan, the second most infected area, the average was only 28 cases. The Al-Madinah region was ranked third with an average of 9 cases, while the Al-Riyadh and Najran regions had fewer than 1 case each. Other regions remained unaffected (Ministry of Health, 2006, 2007, 2008, 2009).

Table 3.11 Dengue fever in Saudi Arabia by region

Region	2006	2007	2008	2009	Average 2006-2009	Average rate 2006-2009 per 10,000 people	Percentage of all cases
Al-Riyadh	0	1	0	3	1	0.00	0.1%
Makkah	1,507	425	902	3,328	1,540	2.60	97.9%
Al-Madinah	7	0	5	2	9	0.06	0.2%
Jazan	29	61	6	15	28	0.23	1.8%
Najran	1	3	0	2	1	0.03	0.1%
Total	1,544	490	913	3,350	1,580		100%

Sources: (Ministry of Health, 2006, 2007, 2008, 2009)

Table 3.11 and Figure 3.2 show the average number of cases of dengue fever per 10,000 people from 2006 to 2009 by region (Ministry of Health, 2006, 2007, 2008, 2009). The most-affected regions of Makkah and Jazan had an infection rate of 2.60 and 0.23 cases per 10,000 people respectively while in the Al-Madinah and Najran regions the rates were much smaller 0.06 and 0.03 cases per 10,000 people. The other regions were fairly untouched (Ministry of Health, 2006, 2007, 2008, 2009). The next section will review the presence of dengue in the Makkah Region.

Figure 3.2 Dengue fever in Saudi Arabia by regions: average rates, 2006–2009 per 10.000 people

Sources: (Central Department of Statistics & Information, 2011; Ministry of Health, 2006, 2007, 2008, 2009)

3.4 Dengue in the Makkah region

3.4.1 Population of the Makkah region

A possible reason for the Makkah region having 97.9% of dengue fever cases in Saudi Arabia could be the large numbers of non-Saudi Muslim people who come through the region. Every year, approximately six million people from around the world visit Makkah City as pilgrims. Another factor could be climate variables such as temperature and humidity in that region. In the following sections the spatial and temporal trends of dengue fever in the Makkah region are identified.

The location of the Makkah region in the western part of Saudi Arabia, with its 12 governorates/cities is shown in Figure 3.3. The two largest cities of the region are Jeddah City (population 3.5m, 50% of the region’s population) and Makkah City (1.7m, 24% of the region’s population) as seen in Table 3.12. The third largest is Ta’if City with 14.3% of the population and all other cities have less than 4% of the population.(Central Department of Statistics & Information, 2011).

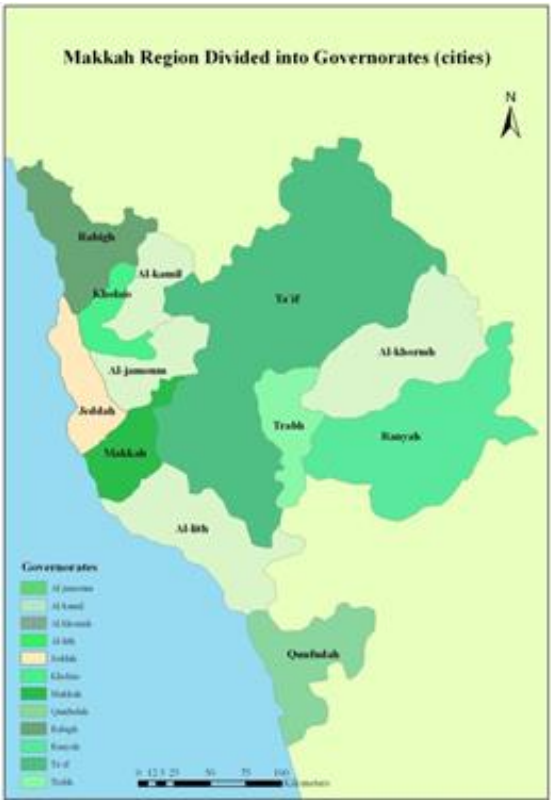

Figure 3.3 Governorates (cities) in Makkah region

Source: (Central Department of Statistics & Information, 2011)

Table 3.12 Governorates (cities) in Makkah Region: Preliminary census results (millions) for 2010

City	Population (millions)	Percentage
Makkah	1.6	24.2%
Jeddah City	3.4	50.0%
Ta`if	0.987	14.3%
Qunfudah	0.272	3.9%
Al lith	0.128	1.9%
Rabigh	0.92	1.3%
Al jamoum	0.092	1.3%
Kholais	0.056	0.8%
Al kamil	0.021	0.3%
Al khormh	0.042	0.6%
Ranyah	0.045	0.7%
Trabh	0.043	0.6%
Total	6.9	100%

Source: (Central Department of Statistics & Information, 2011)

Table 3.13 shows that Jeddah City’s population is comprised of half (50%) Saudi and half non-Saudi residents. Jeddah City has more non-Saudi people (1.7 million) than other cities in the Makkah region because it is one of the most prosperous economic cities in the area and it has the most important seaport and airport in Saudi Arabia. For many years it has been an attractive place for many non-Saudi people to live and work.

Makkah city, the second largest city, also has a large number of non-Saudi people (0.7 million) constituting 44.8% of the population (Central Department of Statistics & Information, 2011). The number of non-Saudi people in Makkah City is high because Makkah City is the holy city for Muslims and many Muslims wish to visit Makkah City and remain there. Many of the non-Saudi people are in the country illegally, and it is quite possible that this statistic could be higher than 44.8% for Makkah City because most of the illegal immigrants do not participate in the census. It is, therefore, quite conceivable that Makkah City has a higher proportion of non-Saudi people than Jeddah City.

Table 3.13 also shows gender differences between Saudi and non-Saudi people. In all governorates there is little difference in gender among Saudi people, with, for most regions, approximately 50% males and 50% females; however, greater gender differences can be seen among the non-Saudis where in practically all cases males outnumber females. Rabigh City has the greatest difference between the genders in Makkah region with 87.7% male and only 12.3% female for non-Saudi people. A possible reason for Rabigh City having the highest number of males is most likely because the presence of big oil companies which employ a large number of non-Saudi people, with more men hired than women. The trend continues to reveal that there are nearly twice as many non-Saudi males than females in those regions (Central Department of Statistics & Information, 2011).

Table 3.13 Governorates (cities) in Makkah region: Preliminary census results for Saudi and non-Saudi people by gender (millions) for 2010

	Saudi				**Non-Saudi**			
City	**Male**	**Female**	**Total**	**Percentage**	**Male**	**Female**	**Total**	**Percentage**
Makkah	0.471 (51.1%)	0.452 (48.9%)	0.924	55.2%	0.473 (63.1%)	0.277 (36.9%)	0.750	44.8%
Jeddah City	0.898 (51.9%)	0.830 (48.1%)	1.7	50.0%	1.1 (64.6%)	0.610 (35.4%)	1.7	50.0%
Ta`if	0.394 (49.3%)	0.404 (50.7%)	0.798	80.9%	0.128 (67.8%)	0.60 (32.2%)	0.189	19.1%%
Qunfudah	0.113 (47.7%)	0.125 (52.3%)	0.239	87.8%	0.027 (83.4%)	0.005 (16.6%)	0.033	12.2%
Al lith	0.055 (49.0%)	0.057 (51.0%)	0.113	88.1%	0.013 (85.0%)	0.002 (15.0%)	0.015	11.9%
Rabigh	0.031 (51.2%)	0.029 (48.8%)	0.60	66.2%	0.027 (87.7%)	0.003 (12.3%)	0.031	33.8%
Al jamoum	0.035 (49.3%)	0.036 (50.7%)	0.71	77.9%	0.016 (82.1%)	0.003 (17.9%)	0.020	22.1%
Kholais	0.023 (48.4%)	0.025 (51.6%)	0.48	85.7%	0.006 (77.9%)	0.001 (22.1%)	0.08	14.3%
Al kamil	0.009 (49.2%)	0.009 (50.8%)	0.18	87.9%	0.002 (86.8%)	0.0003 (13.2%)	0.002	12.1%
Al khormh	0.016 (48.1%)	0.018 (51.9%)	0.34	82.8%	0.005 (78.4%)	0.001 (21.6%)	0.007	17.2%
Ranyah	0.018 (48.1%)	0.020 (51.9%)	0.39	85.9%	0.005 (80.9%)	0.001 (19.1%)	0.006	14.1%
Trabh	0.016 (46.2%)	0.019 (53.8%)	0.36	83.5%	0.005 (77.1%)	0.001 (22.9%)	0.007	16.5%
Total	2.0 (50.7%)	2.0 (49.3%)	4.1	59.5%	1,828.4 (65.3%)	0.971 (34.7%)	2.7	40.5%

Source: (Central Department of Statistics & Information, 2011)

3.4.2 Dengue fever in the Makkah region

Table 3.14, shows the number of dengue fever cases in cities in the Makkah region for four years from 2006 to 2009. Jeddah City had 64.3% of all recorded cases of dengue in the region, while Makkah City had 35.3%. The lowest number of cases (25 in 2009) was in Ta`if City with 0.4% of the total. The other cities in Makkah region did not record any cases (Ministry of Health, 2006, 2007, 2008, 2009). The average number of dengue fever cases per 10,000 people in Makkah from 2006 to 2009 was 3.87 (Ministry of Health, 2006, 2007, 2008, 2009). Makkah City, a smaller city had the highest rate. Jeddah City had a slightly lower rate at 3.51 cases per 10,000 people, followed by Ta`if City at 0.06 cases per 10,000 people (Ministry of Health, 2006, 2007, 2008, 2009).

Table 3.14 Dengue fever in the Makkah region by governorates (cities)

Governorate/ City	2006	2007	2008	2009	Average 2006-2009	Average rate 2006-2009 per 10,000 people	Percentage of all cases
Makkah	199	182	95	1,697	543	3.87	35.3%
Jeddah City	1,308	243	807	1,606	991	3.51	64.3%
Ta`if	0	0	0	25	6	0.06	0.4%
Total	1,507	425	902	3,328	1,540		100%

Sources: (Ministry of Health, 2006, 2007, 2008, 2009)

Jeddah City has an international airport and most Muslim pilgrims come to Makkah City via that airport, and then by bus to Makkah City. In order to maintain control so that only Muslims can enter Makkah City, there is no airport at Makkah City, with pilgrims travelling through Jeddah City to get to Makkah City by bus. Because of this travel route, Jeddah City is highly susceptible to the introduction of dengue fever by the pilgrims who come from counties where dengue fever is already established. Furthermore, the high temperatures and humidity of Jeddah City provide *Ae. aegypti* mosquitoes with a good environment in which to live and spread the disease. Both of these reasons help explain why Jeddah is the city in the Middle East with the highest number of cases of dengue fever and is considered a high priority by the Government for dengue control. The next section will provide details of the occurrence of dengue fever in Jeddah City.

3.5 Dengue fever in Jeddah City

3.5.1 Study area: Jeddah City

Jeddah City lies almost mid-way up the western coast of Saudi Arabia. The Red Sea borders Jeddah City on the west and the Al Sarawat Mountains in the east (Figure 3.4). There are no rivers or valleys in the area. Because of its location, Jeddah City is the second commercial centre of the Middle East after Dubai, and it is also the fourth largest industrial city in Saudi Arabia after Riyadh, Jubail and Yanbu.

According to the 2010 national official census of Saudi Arabia, the population of Jeddah City is 3,430697 (Central Department of Statistics & Information, 2011). In 2009 the largest neighbourhood in Jeddah City was Al Safa with a population of 224,398, whereas the smallest, Al Senaeya, had a population of 853 (Jeddah Municipality, 2010). With a land area of 1,500 square kilometres, Jeddah City has a population density of 2,304 people per square kilometre.

Jeddah City provides a suitable environment for *Ae. aegypti* mosquitoes breeding because of favourable climatic conditions as well as incomplete sewerage network and storm water drainage systems. Moreover, the conditions in Jeddah City are perfect for *Ae. aegypti* mosquitoes breeding: the spread of buildings under construction and the existence of slums, overflowing septic tanks and open water storage tanks, as well as the high level of surface water in many neighbourhoods (Jeddah Municipality, 2009a). In addition, approximately six million pilgrims per year from all over the world move through on their way to Makkah, the Holy City for Hajj and Umrah. As a result, Jeddah City is a central location for dengue fever (Alharthy, 2007). Pilgrims who may be in the incubation stage of dengue could be bitten by a mosquito allowing dengue to spread throughout the region (Alharthy, 2007).

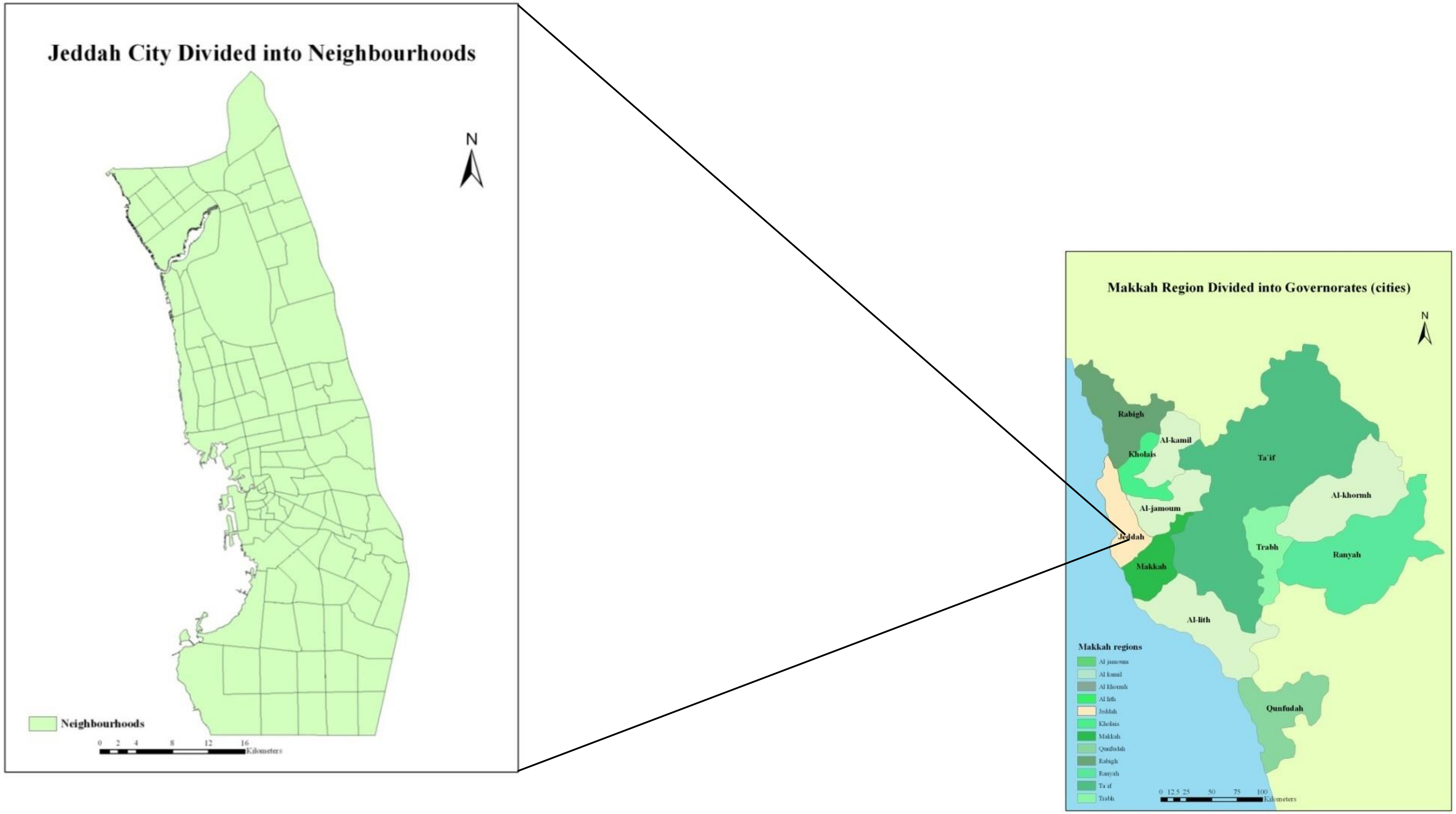

Figure 3.4 Jeddah City located in Makkah region

Sources: (Jeddah Municipality, 2012)

3.5.2 Infected cases in Jeddah City?

Gender variations

Table 3.15 shows the number of dengue fever cases in Jeddah City by gender from 2006 to 2009 (Ministry of Health, 2010). From 2006 to 2009, for Saudi citizens there were more male dengue fever cases (63.4% total) than female (36.6%) and for non-Saudi people, the gender difference was even more marked (83.0% vs 17.0%). Of the non-Saudi population, there were significantly more males than females because of the predominance of non-Saudi males employed in the country. In 2009, there were three cases in which the gender was not stated (Ministry of Health, 2010).

Table 3.15 also depicts the ratio of cases of males with dengue fever to cases of females with dengue fever in 2009 at 3.37:1, an increase from 2.18:1 in 2006. This was the highest ratio observed in the period between the years 2006 to 2009 (Ministry of Health, 2010). This ratio was also higher than those found in any of the previously discussed studies conducted in other regions around the world as discussed above (Agarwal et al., 1999; Goh, 1995; S. Halstead et al., 1970; Ray et al., 1999; Wali et al., 1999).

Variations by age group

The cases of dengue fever by age group in Jeddah City are presented in Table 3.16. The age group 21 - 30 has the largest number of cases of any age group. This is consistent with international studies in Bangladesh, Singapore, and Indonesia (Agarwal et al., 1999; Goh, 1995; S. Halstead et al., 1970; Ray et al., 1999; Wali et al., 1999), discussed earlier in this chapter. The results of the research found that between 2006 and 2009, those aged between 21 - 40 were most affected by dengue and the 11 - 20 age group also had significant numbers. In 2006, there were 345 cases in the 11 - 20 age group and although the number of dengue fever cases greatly decreased in 2007, it rose again in 2008 to 140 cases, and rose again in 2009 to 205. The 21 - 30 age range was more likely to be infected with dengue fever in all four years (Ministry of Health, 2010).

Table 3.15 Number of dengue fever cases in Jeddah City by gender, 2006-2009

YEAR	Saudi			Non-Saudi			Not stated	Total	Ratio Male: Female
	Male	Female	Total	Male	Female	Total			
2006	467 (62.1%)	285 (37.9%)	752 (57.5%)	429 (77.3%)	126 (22.7%)	555 (42.5%)	-	1,307 (33.0%)	2.18:1
2007	90 (68.2%)	42 (31.8%)	132 (54.3%)	84 (75.7%)	27 (24.3%)	111 (45.7%)	-	243 (6.1%)	2.52:1
2008	214 (63.1%)	125 (36.9%)	339 (42.0%)	387 (82.7%)	81 (17.3%)	468 (58.0%)	-	807 (20.4%)	2.92:1
2009	456 (64.0%)	257 (36.0%)	713 (44.5%)	780 (87.6%)	110 (12.4%)	890 (55.5%)	3	1,606 (40.5%)	3.37:1
Total	1,227 (63.4%)	709 (36.6%)	1,936(48.9%)	1,680(83.0%)	344(17.0%)	2,024(51.1%)	-	3,960 (100%)	-

Source: (Ministry of Health, 2010)

Table 3.16 Number of dengue fever cases in Jeddah City by age group, 2006-2009

Age Group	2006	2007	2008	2009	Total
0–10	197	29	52	90	368
11–20	345	39	140	205	729
21–30	383	70	214	511	1,178
31–40	216	53	195	378	842
41–60	144	48	185	354	731
60+	22	4	21	40	87
Unknown	0	0	0	28	28
Total	1,307	242	807	1,606	

Source: (Ministry of Health, 2010)

Variations by nationality

Many people from different countries have visited and settled in Jeddah City. Dengue fever is present in some of the countries from which people have migrated and this may have contributed to the high numbers of dengue fever cases among Saudi nationals. From Table 3.17 it is evident that Saudi nationals have consistently had the highest number of reported dengue fever cases throughout the years 2006 to 2009 (Ministry of Health, 2010).

Table 3.9 shows the difference between the males and females for Saudi and non-Saudi dengue fever cases nationally and highlights that for the years 2006 to 2009 the total number of dengue fever cases was higher for Saudi nationals, at 57.7%. Throughout all four years the number of dengue fever cases was higher for Saudi nationals except in 2008 when the number of non-Saudi dengue fever cases was higher at (56.0%) than Saudi dengue fever cases (44.0%) (Ministry of Health, 2010).

Table 3.17 shows that people from Yemen have had the second highest number of dengue fever cases after Saudi nationals. In 2006, people from Yemen consisted of 16.9% of all dengue cases reported. This number decreased in 2007 but rose again in 2008 and 2009. Yemeni were responsible for 16% of the total cases of dengue fever. The nationality that comes in third is Egyptian. In 2006, they accounted for only 5.3% of the cases but in 2009, the proportion increased to 12.9%. In total, Egyptians had 9% of reported dengue fever cases in those four years (Ministry of Health, 2010).

The Ministry of Health, in investigating the outbreak in Jeddah City in 1994 in which there were two recorded fatal cases of dengue type two infections, found that one of the cases closely matched the strains of dengue type two isolates from East Africa. Before this outbreak, dengue type two transmission had already been identified and confirmed in Somalia, Port Sudan, Djibouti and Yemen. This similarity of the dengue type two isolates from Jeddah City and the East African cases suggests that dengue was introduced from one of these areas (Ministry of Health, 1995).

The level of dengue fever in Jeddah is quite serious and complex, requiring a strong response. In reviewing the situation in Saudi Arabia, Jeddah appears to have a range of factors influencing its high levels of dengue fever, including climate, rapid urban growth, the high non-Saudi population, and migration. The sharp increase in cases in 2006 has led to urgent Government and municipal action to initiate dengue Control Strategies for Jeddah City.

Table 3.17 Dengue in Jeddah City by nationality, 2006-2009

Nationality	Total	2006	2007	2008	2009
Saudi Arabia	1,933 (48.8%)	752 (57.5%)	129 (53.1%)	339 (42.0%)	713 (44.4%)
Yemen	636 (16.0%)	221 (16.9%)	30 (12.3%)	180 (22.3%)	205 (12.8%)
Egypt	355 (9.0%)	69 (5.3%)	22 (9.1%)	57 (7.1%)	207 (12.9%)
Pakistan	217 (5.5%)	50 (3.8%)	19 (7.8%)	36 (4.5%)	112 (7.0%)
Bangladesh	187 (4.7%)	51 (3.9%)	11 (4.8%)	53 (6.6%)	72 (4.5%)
India	175 (4.4%)	23 (1.8%)	12 (4.9%)	75 (9.3%)	65 (4.0%)
Sudan	102 (2.6%)	28 (2.1%)	3 (1.2%)	14 (1.7%)	57 (3.5%)
Chad	62 (1.6%)	26 (2.0%)	1 (0.4%)	18 (2.2%)	17 (1.1%)
Palestine	32 (0.8%)	3 (0.2%)	3 (1.2%)	6 (0.7%)	20 (1.2%)
Not stated	31 (0.8%)	12 (0.9%)	-	7 (0.9%)	12 (0.7%)
Eritrea	23 (0.6%)	11 (0.8%)	1 (0.4%)	4 (0.5%)	7 (0.4%)
Philippines	21 (0.6%)	5 (0.4%)	1 (0.4%)	2 (0.2%)	13 (0.8%)
Ethiopia	19 (0.5%)	12 (0.9%)	-	-	7 (0.4%)
Afghanistan	19 (0.5%)	5 (0.4%)	1(0.4%)	2 (0.2%)	11 (0.7%)
Indonesia	17 (0.4%)	7 (0.5%)	3 (1.2%)	2 (0.2%)	5 (0.3%)
Somali	16 (0.4%)	9 (0.7%)	0	2 (0.2%)	5 (0.3%)
Jordan	15 (0.4%)	1 (0.1%)	3 (1.2%)	3 (0.4%)	8 (0.5%)
China	15 (0.4%)	-	-	-	15 (0.9%)
Syria	14 (0.4%)	4 (0.3%)	1 (0.4%)	2 (0.2%)	7 (0.4%)
Morocco	12 (0.3%)	-	1 (0.4%)	-	11 (0.7%)
Lebanon	11 (0.3%)	-	1 (0.4%)	1 (0.1%)	9 (0.6%)
Burma	10 (0.3%)	4 (0.3%)	-	2 (0.2%)	4 (0.2%)
Turkey	8 (0.2%)	3 (0.2%)	-	-	5 (0.3%)
Nigeria	7 (0.2%)	3 (0.2%)	1 (0.4%)	-	3 (0.2%)
Sri Lanka	5 (0.1%)	4 (0.3%)	-	-	1 (0.1%)
Djibouti	4 (0.1%)	2 (0.2%)	-	1 (0.1%)	1 (0.1%)
Nepal	4 (0.1%)	-	-	-	4 (0.2%)
Mexico	2 (0.1%)	-	-	-	2 (0.1%)
Other countries*	<1 (0.0%)	<1 (0.0%)	<1 (0.0%)	<1 (0.0%)	<1 (0.0%)
Total	3963	1307	243	807	1606

Source: (Ministry of Health, 2010)

*Other countries: Burkina Faso, New Zealand, Tunisia, Canada, Ghana, South Africa, Tanzania, Thailand, UK, Ukraine and USA.

3.6 Control Strategies for Dengue Fever in Jeddah City, Saudi Arabia

In 2006 the Council of Ministers of Saudi Arabia issued an order to control dengue fever cases in Jeddah City. The Control Strategies for Dengue Fever in Jeddah City were designed by three agencies: the Jeddah Municipality, the Ministry of Health, and the Ministry of Agriculture, with advice from WHO consultants. The main goal was to base the plans for the Global Control Strategies for dengue fever on the advice given by the WHO (Jeddah Municipality, 2009b).

In 2006 the Saudi Council of Ministers gave more than USD 378,000,000 to the Jeddah Municipality, Ministry of Health, and Ministry of Agriculture. Following this injection of funds, the Jeddah municipality set up a crisis management team and took the project lead. Once the control strategies were designed, each agency had a different task, and some tasks required collaboration. The remainder of this section discusses the specific tasks of the each organisation, as reported in unpublished documents (Jeddah Municipality, 2009b), supplemented by clarification from key informant interviews.

The Jeddah Municipality founded the Crisis Management department using a group of specialists from different professions. They formulated the Integrated Dengue Control Management Strategy which implemented various methods to reduce the number of dengue cases in Jeddah City. Geographic Information System (GIS) specialists began work monitoring the mosquito population. One method included using spatial distribution parameters for the surveillance devices such as population density, infections cases, and the best distance between devices. As a result of these procedures, a drastic decrease in the population of *Ae. aegypti* was noticed (Alharthy, 2007).

3.6.1 Ministry of Health

Key tasks of the Ministry of Health are laboratory diagnosis and health education. The Strategies to control dengue fever in Jeddah City begin with the Ministry of Health because the Ministry records all dengue fever cases in Jeddah City and sends reports to Jeddah Municipality and the Ministry of Agriculture.

The first step for the team in the Dengue Fever Operations Room in the Ministry of Health is to receive information about new cases and provide a weekly report on these. All health facilities in Jeddah City with suspect blood samples send the blood samples to the Jeddah Regional Laboratory, for analysis, before sending the results to the Dengue Fever Operations Room. Results of confirmed dengue fever cases, together with neighbourhood location are forwarded to the Centre for Diseases Control in the Ministry of Health, and to the Jeddah Municipality and the Ministry of Agriculture. When the Centre for Diseases Control in the Ministry of Health in Jeddah City receives the weekly report they instigate an investigation as follows:

1. Call the case and arrange an appointment. If the case does not respond, this is reported to the Dengue Fever Operations Room.

2. Make an appointment with the male householder. The group from the Centre for Vector Control Diseases, a Ministry of Health official, driver and worker, and someone from the Jeddah municipality visit the case.

3. If the case does not cooperate with the specialist team, they take the GPS points and spray for two kilometres around the residence and report this action to the Dengue Fever Operations Room.

4. If the case cooperates, the Ministry of Health official will provide further information to the people living in the infected house on ways to prevent dengue fever.

Further investigation of the infected site follows, including an assessment of the number of insects in the area. The target area is defined and then sprayed to control mosquitoes in the area. After 10 minutes the dead mosquitoes are collected in special containers and sent to the Laboratory Insect Centre in the Centre for Diseases Control to determine if they are *Ae. aegypti* mosquitoes or not. Random samples from breeding sites both within and outside the home are also collected and tested. The Centre for Diseases Control in the Ministry of Health uses the above data to determine the density of mosquitoes and to calculate the total number of the mosquitoes in each area.

An official from the Centre for Diseases Control reports on the investigation of the surveillance mosquito results to the Dengue Fever Operations Room, along with details of the numbers and density of mosquitoes at the site for entry into the Dengue Fever Operations Room database. The Dengue Fever Operations Room in the Ministry of Health was set up in 2006 and has continued to work with the same Control Strategies until the present.

3.6.2 Jeddah Municipality

The Jeddah municipality has worked on dengue fever and control issues as part of the Government Strategies since 2006. After the dengue fever outbreak in that year, the Mayor formed a crisis management team which then developed a strategic plan of action with a comprehensive operational, technical and scientific methodology for an integrated approach to the control of dengue fever vectors in Jeddah City.

The plan included eleven projects as outlined below, with implementation beginning in 2006.

1. **Laboratory and entomological exploration Project**

The main purpose of this project is to evaluate the effectiveness of pesticides and target them effectively. The first step is to identify mosquito breeding spots through the laboratory analysis of mosquito samples collected daily by exploration insecticide teams. These teams have 504 mosquito traps around Jeddah City and each of these mosquito traps is not moved to a new location until the number of mosquitoes decreases.

Mosquito samples are then classified according to whether it is the *Ae. aegypti* mosquito, or some other vector, to provide field control teams with daily reports of mosquito density as a quality control indicator. The quality of the spray field and control of the mosquito density sites in Jeddah City are assessed by setting light traps in the treatment areas with pesticides. The insects are then classified, and the different light traps are tested and evaluated. Mosquitoes are bred in the laboratory, especially the carrier type of the dengue fever virus, to test the bio-assessment of pesticides that are used, and proposed for use, by the Jeddah City Municipality. The sensitivity levels of the mosquitoes in the field against chemical and biological pesticides used by the Jeddah Municipality in control programmes are investigated. New pesticides that the Jeddah Municipality receives are evaluated before purchase. The final task for the laboratory is to help the employees of various Government sectors, especially those who are from the Jeddah City Municipality, to become well trained and qualified for dengue fever control. The Laboratory also trains students from the University of King Abdul Aziz University in Jeddah City for dengue fever control.

2. Home to Home Project

This project aimed to control mosquitoes inside homes and buildings by spraying the walls and cabinets and corners of the residences and known mosquito resting places. The team in this project uses two methods: non-chemicals for control and source reduction for the mosquitoes in places such as water tanks and old used tyres; and chemicals, spraying 150 to 300 meters around the dengue fever case location as well as in places where there is a high density of mosquitoes.

3. Intensive Control Project

The intensive control project goes further than the *Home to Home* project for controlling and monitoring the mosquitoes by examining all open spaces in the city such as green areas, around the new buildings, schools and industrial areas to reduce the number of *Ae. aegypti* mosquitoes and hence reduce the number of dengue fever cases.

4. Public Awareness Project

The Intensive Control project led to a Public Awareness project to encourage people to make positive behaviour changes and take their own initiatives to reduce mosquito breeding in Jeddah City, with Ministry of Health assistance. This programme's aim is to educate the people about the dangers of dengue fever, and encourage everyone to contribute their efforts to eliminate the spread of disease-carrying mosquitoes.

5. Swamps and water bodies project

The purpose of this project was to monitor and fill the swamps and bodies of water. It also addressed emergency situations that result from flood rain to stop the *Ae. aegypti* mosquitoes from appearing around the swamps.

6. Water tanks/containers project

The aim of this project was to replace all uncovered water tanks used inside houses in the low socioeconomic neighbourhoods where most residents are non-Saudi workers, with clean covered tanks, to reduce the mosquito carrier breeding spots and to provide clean water.

7. Window screens project

This project set out to replace existing window screens with ones that are impregnated with mosquito-repellent chemicals.

8. Geographic information systems project

This project's goal is to provide accurate information to support decision-making that prevents duplication of efforts as this wastes resources. This project also encouraged coordination among different agencies. This is achieved by using ArcGIS to investigate and analyse data on dengue fever cases and dengue fever factors that have been entered into the database.

9. Work Force Management System Project

An electronic system manages all field operations and sends details of all tasks to be implemented on the ground to supervisors. This occurs according to the operational plan on a daily basis. The field supervisors receive those tasks in the field by Personal Digital Assistant (PDA). After field operations are completed, the recorded data are sent directly to the central control system in the Mayor's office to facilitate the monitoring and follow-up workers' various projects.

10. Balanced Score Card Project

The purpose of the Balanced Score Card Project is to evaluate the activities and performance of Government agencies in light of the vision and strategies, as well as the need to accommodate financial and customer perspectives, internal processes, and growth and learning. The system consists of four steps: make the ideas into operational goals, connect the goals to the workers' performance, plan, provide feedback and learning and adjust the Control Strategies.

11. Scientific exchange projects

The purpose of scientific exchanges has been to gain knowledge and exchange experiences. Several foreign delegations, including those from Singapore, visited the

Vector Control Operations headquarters and learned about the technical and scientific procedures that had been put in place. Delegations also visited the Mayor to identify the experience of Jeddah municipality in vector control dengue fever. Delegations from Saudi Arabia visited other countries, such as Singapore, to gain insight into other dengue control projects.

3.6.3 Ministry of Agriculture

The Ministry of Agriculture makes an important and specific contribution to the overall Strategies. The main task of the Ministry of Agriculture is to control dengue fever outside the city limits. They perform ground and aerial sky controls for *Ae. aegypti* mosquitoes. On the ground they spray chemicals in remote areas and around farms as well as placing traps to monitor mosquitoes. The Ministry of Agriculture can increase their level of activities depending on the density of the mosquitoes. Another task the Ministry of Agriculture undertakes is aerial spraying for more distant and difficult areas.

The Jeddah City Municipality, Ministry of Health and Ministry of Agriculture have been working as a team to fight and control dengue fever in Jeddah City. Each is responsible for its own area of work. They often convene to discuss their work and problems, and in some cases they are able to help each other. These Control Strategies for dengue fever in Jeddah City have shown positive results in some years since 2006, and less good results in other years. In Chapter 6 the work of the Jeddah City Municipality, Ministry of Health and Ministry of Agriculture is examined through key informant interviews to understand how these Control Strategies have been carried out in Jeddah City.

3.7 Summary

This chapter has discussed various trends in dengue fever in Saudi Arabia. It has set out how dengue fever is distributed throughout the regions in the country and identified the areas that have the highest number of cases along with the Government's Strategies and plans for control. Dengue fever in Saudi Arabia was investigated at regional and city levels. Most dengue fever cases registered in Saudi Arabia occurred in the Makkah region. Jeddah city in the Makah region reported the highest number of dengue fever cases in the Kingdom, with the number of male cases outweighing the number of female cases. The age group of 15 - 44 years was shown to have more dengue fever cases than any other age group across the years. Analyses of the demographic variations (gender, age, and nationality) showed overall that Saudi males, in the age group 21 - 30 have the highest number of dengue fever cases in Jeddah City.

In response to the high numbers of dengue fever cases, the government has developed and implemented comprehensive Strategies to control dengue fever in Jeddah City. The Ministry of Health, Ministry of Agriculture and Jeddah Municipality all share a common goal and have different tasks: to eradicate and reduce the number of dengue fever cases. The Strategies for managing dengue fever in Jeddah City are well set out, but little is known about their effectiveness.

The Control Strategies for dengue fever in Jeddah City appear well designed and follow WHO recommendations and the WHO Control Strategy 2000. However, looking at the number of cases between 2006 when the Control Strategies started, and 2009, the number of cases actually increased between 2007 and 2009 which means that the Control Strategies may have been less effective than hoped. This suggests, based on the literature from Chapter 2 and the review of the Jeddah situation in Chapter 3, that (i) alternative approaches to analysing the dengue-related data for Jeddah City, and (ii) a more critical, evaluative approach to the Strategies may be required. These approaches become the basis for the research in this thesis, as set out in Chapter 4. Chapter 5 discusses the quantitative methods used to analyse dengue fever factors in Jeddah City neighbourhoods, and Chapter 6 discusses the qualitative methods that were used to examine implementation of the Control Strategies for dengue fever in Jeddah City.

Chapter 4: Methodology

4.1 Introduction

Two aspects of the WHO Global Strategy for Dengue Prevention and Control, 2012-2020, the technical elements and enabling factors, were identified in previous chapters as helpful for developing a framework to consider research into the problem of dengue fever in Jeddah City (WHO, 2012). The research component of the technical elements included a geographical perspective that is used to investigate and analyse the spatial and temporal distribution of dengue fever across neighbourhoods in Jeddah City. The five enabling factors set out in the Global Strategy (advocacy and resource mobilisation; partnership, coordination and collaboration; communication to achieve behavioural outcomes; capacity building; and monitoring and evaluation) provided the basis for interpreting the findings from key informant interviews to assess the progress of implementation of the dengue fever Control Strategies in Jeddah (WHO, 2012).

The overall aims of this research are to assess the social and physical environmental neighbourhood influences on the pattern of dengue fever, and make a preliminary determination of progress towards implementation.

Objectives

- To describe the spatial and temporal trends of dengue fever distribution in Saudi Arabia.
- To assess the relationship between neighbourhood physical and social environmental characteristics in Jeddah City and the distribution of dengue fever.
- To evaluate the response of relevant agencies to the problems of dengue fever in Jeddah City.

4.2 Mixed methods methodological approach

4.2.1 The mixed methods approach

A mixed methods approach is used in this research. Overall, the mixed methods tradition has only been around in the last few decades and so has not been as well developed as the independent use of qualitative and quantitative methods (Bergman, 2008). Mixed methods is a research design that uses both quantitative and qualitative approaches but in a variety of sequences and for different purposes. Researchers who use mixed methods support a pragmatic approach which looks to clarify myths or truths, and focuses on whatever methods work to achieve this. Data to answer research questions can take both a narrative and/or a numerical form (Tashakkori & Teddlie, 2003). Mixed methods first appeared in the 1950s when methods were often combined to explore issues when there was little information available. This idea of mixing two or more methods was suggested by Denzin as a way of giving greater credibility to research conclusions. In the 1990s mixed methods became the new paradigm that was considered a bridge between the methods already available to researchers working with complex problems (Giddings, 2006).

Mixed methods research has become increasingly popular as a recognised research design methodology, and combines data from qualitative and quantitative approaches (Bergman, 2008). According to some researchers it has also been deemed as the "third path" or "third paradigm" (Teddlie & Tashakkori, 2009). This type of research is used as an alternative to exclusively quantitative or exclusively qualitative methods. It has evolved from using one method, either qualitative or quantitative, and then supplementing it with another. This acceptance of a mixed methods approach took place in two stages. The first phase was from the 1960s to the 1980s which involved the acceptance of using mixed methods to compensate for the weakness of using exclusively qualitative or quantitative methods. The second stage, which began in the 1990s, has a more integrated approach combining both qualitative and quantitative methods in the research process to achieve a more comprehensive understanding of an issue (Teddlie & Tashakkori, 2009).

This integrated approach has been given several names. It has been called blended research (R. M. Thomas, 2003), integrative research (Johnson & Onwuegbuzie, 2004), multi-method research (Hunter & Brewer, 2003; Morse, 2003), and triangulated studies

(Sandelowski, 2003). A leader in the field, John Creswell, defined mixed methods research as a research design where the researcher gathers, analyses and mixes quantitative and qualitative data in one study or in a multiphase programme of investigation (Johnson, Onwuegbuzie, & Turner, 2007).

Mixed methods research can be used in any study when the results of qualitative and quantitative methods can be usefully applied to a theoretical structure that provides an answer to the research question (Teddlie & Tashakkori, 2009). There are two broad approaches to structuring a mixed methods study: a sequential or a concurrent approach. The purpose of the sequential approach is to obtain results from one method in order to plan for another. In contrast, in a concurrent or parallel approach (Creswell, Fetters, & Ivankova, 2004), both quantitative and qualitative methods are used simultaneously (Johnson et al., 2007). In highly complex situations, the methods and perspectives can be deliberately mixed from the beginning of the research process. (Johnson et al., 2007).

There are numerous studies in health research using mixed methods. Two useful papers by O’Cathain et al. (2007) and Creswell et al. (2004), provide examples of the value of this approach. O’Cathain et al. (2007) analysed proposals and reports of 75 mixed methods studies that were funded by a commissioner of health services research in England to determine how often mixed methods were used in the research process. Eighteen percent of the studies they analysed contained mixed methods approaches. A mixed methods approach was primarily used to obtain funding and establish credibility over time. Some of the benefits of using mixed methods include the ability to have a more comprehensive research study which may not be achieved through quantitative methods alone. Health service researchers can contribute further to developing mixed methods research in a variety of health related contexts (O'Cathain, Murphy, & Nicholl, 2007). In the Creswell et al. (2004) study, five published mixed methods studies in primary care were analysed by using criteria present in the social and behavioural science literature in North America and a report of the National Institutes of Health. The criteria included identifying reasons for mixing both quantitative and qualitative data, the types of data collected and analysed, the priority given to both methods, the sequence of implementation, and the phase in which the integration of the collection and analysis of both methods occurred. These five criteria were used as a template for analysing mixed methods in primary care studies. It was found that three design models are recommended as organising frameworks for primary care investigators: the Instrument Design Model, Triangulation Design Model, and the Data Transformation Design Model. The application of one of these design models was assessed as giving credibility to the mixed methods investigations in primary care (Creswell et al., 2004)

Mixed methods are sometimes described as not replacing either quantitative or qualitative research but drawing on the strengths and minimising the weaknesses of each. Mixed methods can be thought of as being positioned in the middle of a continuum covering a large set of points. It provides a way for researchers to describe and to develop techniques that help bridge any tensions between quantitative and qualitative research (Johnson & Onwuegbuzie, 2004).

Mixed methods research, however, has not always been received with complete acceptance among researchers. Some argued that there were drawbacks, such as having a probability of contradictory results because of using more than one method. Some opponents of mixed methods approach believe that reasons given for mixing methods are sometimes ambiguous and unsatisfactory, and much information and key ideas could be overlooked or simply left out. It may be questionable to some whether using a mixed methods strategy is better than using a single method design (Tashakkori & Teddlie, 2003). Another perceived weaknesses is that it can be difficult for an individual researcher to use both qualitative and quantitative methods, whereas a research team may be able to do so more effectively. Furthermore, mixed methods research design requires the researcher to learn about a number of methods and approaches and learn how to mix them appropriately. Furthermore, it can be expensive and time consuming for a single researcher (Johnson & Onwuegbuzie, 2004). Yet, many researchers believe that it is an acceptable way to conduct research resulting in positive outcomes, and particularly it can meet the research needs of complex situations (Yin, 2014).

Mixed methods approaches, as used in this research use a combination of both quantitative and qualitative methods. Thus it is important to provide a brief overview of each approach and its limitations.

4.2.2 Quantitative methods

Quantitative methods can be defined as the techniques involved in collecting, analysing, interpreting and presenting numerical information. In quantitative data analysis the objective is to take measurable amounts of specific data, then describe and test specific research hypotheses (Amaratunga, Baldry, Sarshar, & Newton, 2002). Positivists consider that their research is completed in an objective environment devoid of any values that may have affected how they performed their analyses and interpreted their results. The research hypothesis is a question which uses predictions based on theory or precedence, that itself is based on relationships of social phenomena established prior to doing the research study. Data analysis in quantitative methods uses techniques that describe the problem or area of interest, and looks for differences and relationships between variables (Teddlie & Tashakkori, 2009).

Quantitative analysis can be described as the analysis of numeric data using a variety of statistical techniques. Quantitative data can be categorised in many different ways, and involves three distinct qualities. First, the data can be grouped according to either descriptive or inferential methods (Amaratunga et al., 2002). Descriptive methods summarise data to find trends and patterns. Inferential techniques are performed later and are primarily used to test hypotheses or confirm results from the descriptive data. Second, quantitative data analysis can be distinguished by its univariate and multivariate procedures. Univariate analyses generally focus on simple relationships between variables but tend to neglect the possible effects of confounding factors. Multivariate analyses, on the other hand, generally focus on a variety of different variables, including multiple dependent and independent variables and the relationships between them. However, while such approaches were an improvement on simple univariate analyses, they still suffer from many of the same problems as positivist generalisations by neglecting the impact of cultural context (Teddlie & Tashakkori, 2009). In addition, by often relying heavily on official census data, quantitative analyses are also subject to problems arising from the ecological fallacy and the modifiable unit area problem (MAUP) whereby different representations of spatial data may provide differing research results (Swift, Liu, & Uber, 2014). Most of the research on dengue fever reported in Chapter 2 relied on quantitative methods to examine the relationships between dengue fever and the various factors that influence its spread (Joshi et al., 2006; Khormi et al., 2011; Promprou et al., 2005; Schmidt et al., 2011; Stevenson et al., 2009; Syed et al., 2010; Wu et al., 2007).

4.2.3 Qualitative methods

Unlike quantitative methods, the qualitative tradition uses techniques connected with collecting, analysing, interpreting and presenting narrative and observational information. Data sources could include public and private documents or interviews of various kinds (e.g. key informant, in-depth, or focus group interviews) (Saks and Allsop, 2007). Questions may be open or closed, or a combination of both. The interviewer in qualitative research is able to seek more information to clarify any ambiguities within the responses. Qualitative interviews tend to contain open-ended and more general questions than quantitative interviews which, while having more structure, tend to use closed-ended questions which limit the range of responses (Saks & Allsop, 2007).

Qualitative methods also seek to understand the meaning of a problem to the group affected. In order to secure this information, in-depth interviews, focus group interviews and participant observations can be used. Qualitative work can be used as a first step in survey design to develop questions for a survey tool, for example, to ensure that terminology used in the questionnaire is relevant to respondents or provides insights into key issues identified by participants, which can then be addressed in subsequent surveys. Furthermore, in health services research, qualitative methods can investigate the meaning of survey results and, for example, assess possible service options to meet identified needs (Green, 1999).

Researchers using qualitative methods adhere to the idea of constructivism. Constructivists argue that researchers, independently and collectively, create or construct the meaning of the phenomena under investigation, based on the narratives of participants. The results of such analyses are often reported as themes (Creswell, 2012; Egon G Guba & Lincoln, 1994; N. Mackenzie & Knipe, 2006; Teddlie & Tashakkori, 2009).

4.2.4 Mixed methods approach to examining dengue fever in Jeddah

To achieve the research objectives for this study a concurrent mixed methods research design using quantitative and qualitative data is used. Quantitative data are available from the Saudi Government for dengue fever cases as well as some of the spatial and temporal variables associated with them. Qualitative information was obtained from interviewees who are, or who had been, working on the official dengue fever Control Strategies. Both methods are used in this thesis to understand the complexities of the dengue fever problem and its management in Jeddah City.

A concurrent mixed methods approach was applicable to understanding the situation of dengue fever cases in Jeddah City. A quantitative approach was used to analyse the spatial and temporal distribution of dengue fever across neighbourhoods (reported in Chapter 5). Qualitative data were used to understand the progress of Government control projects (reported in Chapter 6). While it may seem that a sequential approach might have been appropriate, with the findings of a quantitative study informing the design of interviews, difficulties with the quality of and access to data meant that the time frame of a PhD thesis could not accommodate a sequential approach. Nevertheless, the different data sources and analytical tools of quantitative and qualitative analysis provided opportunities for greater insights in the interpretation of a complex situation and to achieve the goals of this thesis.

4.3 Research methods

The following section outlines the particular methods adopted using a mixed methods approach to achieve the thesis objectives.

4.3.1 Quantitative research

4.3.1.1 Data sources

This proposed research project required a substantial amount of data from a variety of sources.

Dengue fever case data

The total number of dengue fever cases from 1994 to 2010 for Saudi Arabia was obtained from the Health Statistical Year Book from 2006 to 2010 published by the Ministry of Health. This included the location of dengue cases at a regional and city level with the data further being broken down by age group and ethnicity (Saudi and non-Saudi). In addition, the weekly number of dengue fever cases data from 2006-2009 for Jeddah City neighbourhoods were obtained from the Ministry of Health. These data sets were not published and it required contact to be made with the Jeddah City Dengue Fever Operation Room at the Ministry of Health to obtain the data. This was received by e-mail as an Excel spreadsheet and included information on the nationality, gender, and age of the people infected with dengue fever in different neighbourhoods in Jeddah City.

Population data

The last census undertaken in Saudi Arabia was in 2010 and to date only limited data have been published by Central Department of Statistics and Information Department, on their website. Data were not available at neighbourhood level population for Jeddah City despite repeated contacts being made, the last being in 2014. Nonetheless, although detailed neighbourhood population data were unavailable from the 2010 Census, some data from the Jeddah Urban Observatory at the Jeddah Municipality provided estimates of the population of Jeddah City neighbourhoods in 2009. This data, in conjunction with the area size of the neighbourhoods, provided not only population estimates for 2009 but also enabled the calculation of neighbourhood population densities. Even so, none of the 2010 census data, nor the 2009 estimates, included disaggregated data by age, ethnicity, or gender. This level of detail was available for the earlier 2004 Saudi Census and provided the opportunity to derive further neighbourhood population estimates for 2005-2008.

Visitors to Saudi Arabia

Selected data for visitors' nationality and purpose for visiting Saudi Arabia were obtained from the published Tourism Information and Research book from 2006 (Tourism Information and Research, 2006).

Socioeconomic status

Socioeconomic status data for Jeddah City neighbourhoods were not available from any official sources. The Central Department of Statistics and Information Department and Jeddah Municipality were contacted by the researcher in person in an attempt to obtain socioeconomic information; however, nothing was forthcoming. As an alternative, the researcher used a modified Delphi approach, itself a qualitative research method, to develop the required socioeconomic status variable for Jeddah City.

The Delphi method uses a panel of experts whose opinions are elicited on a research question or area of study. The main purpose of this is to have the experts' opinions come together towards optimal clarification of the area of enquiry and achieves a high degree of reliability (Baumfield, Conroy, Davis, & Lundie, 2012).

This method has been used widely to develop consensus on various topics, for example, selecting healthcare quality indicators (Boulkedid, Abdoul, Loustau, Sibony, & Alberti, 2011), forecasting tourism activity (Bosun & Modrak, 2014), and identifying farm ponds' preservation values and spatial location (Lee, Chou, & Wu, 2013). This is the first time, however, that the Delphi method has been used in the Middle East to develop an assessment of neighbourhood socioeconomic status. The Delphi process usually involves several rounds of compiling opinions from expert sources. The resulting opinions are then synthesised to form a group judgement which can be applied to a particular problem (Gordon, 1994). The Delphi method depends on a continuous cycle of questioning, collecting information, summarising and then refining the opinions to maintain focus to make best use of the experts' contributions towards the main concerns of the researcher (Baumfield et al., 2012).

To apply the Delphi method to this project a checklist (Appendix 1**)** was sent by e-mail to 32 specialists who have professional knowledge of Jeddah City neighbourhoods, and who work in Jeddah. These specialists were contacted through their organisations, and of the 25 participants who replied, 11 were from a Government agency, 10 from academia, and four were from a financial institution. In brief, the checklist invited them to describe the socioeconomic status of individual Jeddah City neighbourhoods. They were provided with a list of neighbourhoods, linked to a map to show the location for each neighbourhood, an individual to mark the neighbourhood as low, middle and high. No guidance or criteria for the selecting categories were given anonymity. The participants completed the checklist and e-mailed it back to the researcher.

Once the completed checklists were received, the 25 responses were tabulated according to the frequency of a high, middle, or low socioeconomic status rating for each neighbourhood. These rankings were used to derive a score based on the percentage of ranks in each socioeconomic status category. The highest percentage of any socioeconomic status category was chosen as the socioeconomic status ranking of the neighbourhood. These results were then sent to the respondents for comment and most of them agreed with the final results for the socioeconomic level for the neighbourhoods. For those who disagreed, they believed that some of the middle socioeconomic status neighbourhoods contained areas that more closely resembled low status neighbourhoods because of their close proximity to each other.

To demonstrate the socioeconomic status level of the neighbourhoods, several photographs were taken by the researcher. Figure 4.1-Figure 4.6 show photographs of the quality of housing and buildings that characterise the socioeconomic classifications 1 (*high*) –3 (*low*). In the high socioeconomic status neighbourhoods (Level 1) the housing conditions are very good with most of the villas built for one or two families (Figure 4.1). Figure 4.2 shows that the Government had provided leisure areas for the high socioeconomic status neighbourhoods, including sport fields and recreational facilities. The high socioeconomic status neighbourhoods typically have a low population density with larger land areas for the houses and a street to accommodate two or three car lanes. Those neighbourhoods have good quality water and sewage networks and pipes provided by the Government. Most people living in those neighbourhoods are Saudi, and most of the houses have at least two people who are non-Saudi employed at the home. One of them usually works as a male driver and the other as a female house worker.

Figure 4.1 High socioeconomic status neighbourhood

Figure 4.2 Entertainment area in high socioeconomic status neighbourhoods

The middle socioeconomic status neighbourhoods (Level 2) are quite different from the high socioeconomic status areas. Housing comprises predominantly apartment buildings located near to market areas as seen in Figure 4.3 and Figure 4.4 Most of these neighbourhoods are quite high density and predominantly Saudi, with more than 6-8 people including one non-Saudi house worker living in a 4 to 5 bedroom apartment. People living in these apartment buildings have difficulties finding a place to park, with the each family having an average of 2 to 3 cars. Because of the high population density, water and electricity supply may be interrupted, especially in the summer season, because each room must have its own air conditioning (Naffee, 2014; Shehab, 2013).

Figure 4.3 Middle socioeconomic status neighbourhood

Figure 4.4 Market in middle socioeconomic status neighbourhood

The worst housing and living conditions in Jeddah City can be seen in the low socioeconomic status neighbourhoods (Level 3) where housing and the surrounding environment are poor (Figure 4.5). These neighbourhoods are considered poor because most of them are old, and the people who are living there are mostly non-Saudi due to the low cost of housing. These are the only areas where non-Saudis can afford to live. In the past, Saudi people used to live in those neighbourhoods, but they were able to relocate to new and more modern neighbourhoods which are classified as middle and high socioeconomic status. The neighbourhoods located in the centre and south Jeddah City have high population densities. Besides there being poor housing conditions, at times there is no electricity or water available (Naffee, 2014; Shehab, 2013). People living there have problems with a shortage of water and therefore resort to saving water in tanks to use when needed. Figure 4.6 shows that the drainage network is not adequate; only a little rain is needed for surface water to appear because the sewage network is poor and sometimes may not exist at all (Figure 4.5and Figure 4.6). The photographs of the poorest neighbourhoods (Figure 4.5 and Figure 4.6) were not taken by the researcher because he was advised by a local photojournalist that those neighbourhoods were considered as a "no-go" area with a high risk of getting into trouble when taking photographs there.

Figure 4.5 Low socioeconomic status neighbourhood

Source: (Azzazy, 2013)

Figure 4.6 Surface water in low socioeconomic status neighbourhood
Source: (Garoch, 2011)

Climate data

The climate data for the daily temperature, humidity, and rainfall for Saudi Arabia and Jeddah City from 2006 to 2009 was obtained by e-mail from the *Presidency of Meteorology of Jeddah City*. These data were used to determine the relationship between dengue fever and climate. Although no neighbourhood climate data were available it was still possible to examine monthly and weekly variations in the above indicators for Jeddah City and to correlate these with trends in the number of dengue fever cases at the neighbourhood level.

Quantitative methods were used to address two research objectives, which are now discussed in turn.

4.3.1.2 Objective 1: To describe the spatial and temporal trends of dengue fever in Saudi Arabia.

In this objective, three questions were asked to understand the situation of dengue fever in Saudi Arabia:

1. From 2006 to 2009, which regions in Saudi Arabia had registered cases of dengue fever?

2. From 2006 to 2009, which cities in Saudi Arabia had registered cases of dengue fever?

3. Who is most likely to be infected by dengue fever in Jeddah City? What are the demographic variations by age, sex, and nationality?

For these questions a variety of quantitative approaches were used (see chapter 5), compiling dengue fever cases data and the census data for the 13 regions in Saudi Arabia, followed by a specific analysis of the Makkah region and Jeddah City. Dengue fever numbers and case rates were examined at different spatial scales for the regions and cities in Saudi Arabia. The location of the dengue fever cases and demographic differences in regions and cities in regards to gender, age, and nationality were closely studied.

4.3.1.3 Objective 2: To assess the relationship between neighbourhoods physical and social environmental characteristics in Jeddah City and the distribution of dengue fever.

To achieve this objective, four main questions were asked:

1. What is the spatial distribution of dengue fever in Jeddah City's neighbourhoods?
2. To what extent is there evidence of spatial and temporal clustering of dengue fever cases?
3. What types of neighbourhood explanatory variables are important for the spatial distribution of dengue?
4. What impacts do climate variations have upon the incidence of dengue and is there any interaction with neighbourhood factors in Jeddah City?

(1) The spatial distribution of dengue fever cases in Jeddah City neighbourhoods

To understand the distribution of dengue fever in Jeddah City from 2006 to 2009 the number of dengue fever cases per 10,000 people in Jeddah City neighbourhoods was mapped for each year.

(2) Is there evidence of spatial and temporal clustering of dengue fever in Jeddah?

This question comprised two parts. First, after finding Jeddah City to be the most affected city in Saudi Arabia, the hot spot analysis Getis-OrdGi tool in ArcGIS 10.1 was used to identify hot spots of dengue fever in Jeddah City. The data comprised the average number of dengue fever cases per 10,000 people from 2006 to 2009. After the high and low hot spot neighbourhood clusters were identified, the mean and standard deviation of neighbourhood characteristics in the high and low hot spots were analysed to determine the key factors differentiating the two types of areas. The neighbourhood characteristics chosen were the average number of dengue fever cases and the average rate of cases per 10,000 people for 2006-2009, population density for 2009, the sex ratio for Saudi and non-Saudi males per 100 females for 2004, the percentage of non-Saudi people in 2004 and neighbourhood socioeconomic status for 2013.

The second part of this analysis aimed to determine whether there was a spatial spread of dengue fever away from the hot spots. Weekly variations in the number of dengue cases were examined for all years and the neighbourhood which had the largest number of cases in a given year was defined as the *peak week neighbourhood* for that year. After finding the neighbourhood which had the major peak in dengue fever cases, the number of cases in surrounding neighbourhoods over the following three weeks was examined to determine the pattern of change. This descriptive analysis of the spatial spread of the dengue fever was undertaken for all years except 2007 when there were very few cases. It provided a temporal snapshot into patterns of change and it also provided the opportunity to go beyond a simple cross-sectional analysis.

(3) Explanations of Neighbourhood Variations in Dengue Fever

The third objective sought to address three questions: (1) what neighbourhood physical and social characteristics provide important explanations of dengue fever case rates, and to what extent is their impact consistent through time; (2) what are the key pathways between neighbourhood socioeconomic status and the incidence of dengue fever and; (3) to what extent has the presence of surface water been a significant environmental factor affecting the incidence of dengue fever?

To answer the first question bivariate correlations were calculated to find the relationship between dengue fever case rates per 10,000 people for each year for 2006-2009 and neighbourhood physical and social characteristics. Neighbourhood characteristics included: measures of population density (2009), the percentage of non- Saudi people (2004), the percentage of Saudi people (2004), the sex ratio for Saudi and non-Saudi (males per 100 females, 2004), and neighbourhood socioeconomic status (2013). This was defined as the proportion of respondents who defined the neighbourhood as one of low socioeconomic status. In addition, two neighbourhood physical characteristics were included; the percentage of land area in a neighbourhood covered by surface water for each year 2007 to 2009 and the presence of surface water in adjacent neighbourhoods within a two and three kilometre radius (buffer zone) from 2007 to 2009.

In order to understand the relationship between neighbourhood physical and social characteristics and dengue fever case rates across time, stepwise multiple regression was used. In a stepwise regression, using the forward selection method, predictor variables are entered into the regression equation one at a time based upon statistical criteria, in this case whether they were significant at the $p<0.05$ level. At each step in the analysis the predictor variable that contributes the most to the prediction equation, in terms of increasing the multiple correlation, is entered first. This process is continued for all remaining variables not in the equation and is dependent upon their partial correlations with the dependent variable and their *p*-values. When there are no longer any additional significant predictor variables the analysis stops.

All the other explanatory variables were tested again to determine whether they were significant to the model. If their contribution were lacking, then the variable was removed. This method selects the most valuable explanatory variables that contribute to the results. All the models used the dengue fever case rate for each year and the average dengue fever case rate from 2006-2009 as dependent variables. Three different models were used to examine and understand the influence of the population variables separately in the beginning and then more explanatory variables were added in the next two models to show how the influence of the population variables can be changed.

The first model used just population variables, namely population density, the Saudi and non-Saudi sex ratio and percentage of non-Saudi people. The second model used the same variables but with the addition of neighbourhood socioeconomic status. The third model included the above variables along with the two indicators of neighbourhood surface water conditions. All those models can help determine which risk factors were more conducive to increasing dengue fever case rates in Jeddah City neighbourhoods.

The second question attempted to assess the importance of the three different pathways discussed in Chapter 2 which may help explain the relationship between neighbourhood socioeconomic status and dengue case rates. The three pathways are: (1) neighbourhood population densities, (2) the presence of migrant groups and (3) neighbourhood lifestyle/local cultures. The pathway analysis used partial correlation analysis to determine the extent to which the relationship between neighbourhood socioeconomic status and dengue case rates (for each year 2006-2009) remained, after controlling for possible intermediary confounders. The controlled explanatory variables used were population density and the percentage of non-Saudi people for each year. In the beginning population density was controlled, and then population density and the percentage of non-Saudi people were controlled together. The results from these analyses attempt to understand the different ways in which neighbourhood socioeconomic status is linked to dengue fever case rates in Jeddah City neighbourhoods.

The third question aimed to examine the importance of surface water in affecting dengue case rates. The surface water problem was studied by mapping water conditions using two measures: the proportion of a neighbourhood's land area covered in surface water for each year (2007-2009), and the amount of surface water present in surrounding neighbourhoods within a two and three kilometre radius from the centre point area of the neighbourhoods using ArcGIS 10.1. The two and three kilometre buffer zone was chosen because it can fit in most of the neighbourhood areas. In addition to examining the relationship between dengue fever case rates and the presence of neighbourhood surface water, consideration was also given to the extent to which such conditions also varied by neighbourhood socioeconomic status. Means and standard deviations of the two surface water characteristics were thus computed for high, middle and low status neighbourhoods as well as bivariate correlations between neighbourhood socioeconomic status and surface water conditions.

(4) The effect of climate factors on dengue fever case rates and how seasonal variations in dengue are related to neighbourhood social conditions.

The final question aimed to examine the different relationships between climate variables and dengue fever cases. Two analyses were undertaken to examine the impact of climate variations on dengue fever in Jeddah City. The first analysis examined the extent to which climatic variables influenced the number of dengue fever cases in Jeddah City as a whole, while the second analysis investigated the extent to which seasonal variations in the number of dengue fever cases occurred by neighbourhood social status.

The first analysis used data on the total number of dengue fever cases per week along with measures of the weekly mean, maximum, and minimum values for temperature and humidity. The data covered all weeks in the period 2006 to 2009, which were divided into the total number of dengue fever cases per week, the weekly mean, maximum and minimum of temperature and humidity into quartile groups, ranging from 1 (*lowest*) to 4 (*highest*). Cross tabulation analysis in SPSS was used for the weekly dengue fever cases and temperature and humidity variables to understand the linear relationship between the total number of dengue fever cases per week with weekly average of maximum and minimum temperature and humidity. The result of this cross tabulation analysis can show the total number of dengue fever cases per week and whether the odds ratios increased or decreased in each quartile group when the influence of weekly average of maximum and minimum temperature and humidity changed in 2006 to 2009.

The second analysis examined the relationship between weekly variations in the number of dengue fever cases and neighbourhood socioeconomic status. The number of dengue fever cases per week in low, middle, and high status neighbourhoods was graphed in order to investigate whether distinct seasonal variations in the number of cases occurred in different status neighbourhoods. In addition, correlations between the weekly number of dengue fever cases and the average (weekly) mean temperature and humidity were also undertaken for different types of neighbourhoods. It was expected that the impact of seasonal climatic variations would be most marked in lower socioeconomic neighbourhoods.

4.3.2 Qualitative study

4.3.2.1 Objective 3: To evaluate the response of relevant agencies to the problems of dengue fever in Jeddah City.

This objective incorporates two sub-objectives related to the evaluation of the Government’s efforts to prevent and to control dengue fever:

- To assess the strategic approaches to dengue fever used by public authorities.
- To assess the capacity and capability of operational groups in the Ministry of Health, the Jeddah Municipality, and Ministry of Agriculture in relation to dengue fever in Jeddah City.

The qualitative approach used for these sub-objectives combined two different data sources: documentary sources (see 4.3.2.2 below) and key informant interviews (see 4.3.2.3 below). The two sources were integrated into a qualitative descriptive analysis. Qualitative description is a specific research technique that analyses data collected from a small group of respondents, in this case supported by explanatory documentary sources. Qualitative description is useful in health services research to examine institutional and social factors, identify opportunities for change, and to understand the reasons for the success or failure of interventions (Starks & Trinidad, 2007). Furthermore, qualitative description is useful in exploratory studies because the researcher allows the data to “speak for itself”, with minimal interpretation other than being systematically organised (Neergaard, Olesen, Andersen, & Sondergaard, 2009). Respondents are asked to express their concerns, feelings, and attitudes regarding a situation or event and to provide direct descriptions of what has taken place (Sandelowski, 2010). For these reasons qualitative description is highly appropriate for this particular project because of the absence of prior qualitative research in this area.

The information obtained is based on personal reports and, because of the way in which data were collected and analysed, such research has often been considered invalid or as being of low credibility (E. Thomas & Magilvy, 2011). Despite the negative connotation of being a collection of subjective experiences, it is a frequently used methodological approach and, as noted by Thomas and Magilvy (2011), rigour can be maintained.

4.3.2.2 Documentary sources

The Government documents used were drawn from the Jeddah City Municipality, Ministry of Health, Ministry of Agriculture and the Saudi Arabia Central Department of Statistics and Information. These documents helped in understanding what the Saudi Arabia Government has done, and is continuing to do, to control dengue fever in Saudi Arabia and especially in Jeddah City. Some of these documents were unpublished but fortunately a number of unpublished documents and reports were available for research purposes. For example, it was possible to obtain the unpublished Control Strategies plan for dengue fever in Jeddah City as designed by the Jeddah Municipality. Similarly, the Ministry of Agriculture also provided information relating to their dengue control activities outside the city limits of Jeddah City.

Besides relying on local documents, to understand the progress of the Strategies, it was necessary to gain information from people who were working in the area. The method chosen for this was key informant interviews, as set out in the next section.

4.3.2.3 Key informant interviews

Key informant interviews were used to acquire information from people, who had first-hand knowledge of, and expertise in, the way in which the dengue fever Strategies were implemented. Such an approach to understanding policy implementation has been used extensively in health services research. One study from Mississippi used key informants to understand the perceptions of nutrition and health needs in southern rural communities prior to nutrition intervention planning (Yadrick et al., 2001). Another study used key informants to examine the meaning of the terms *integration* and *collaboration* for practitioners and other key informants working in multi-professional health care teams with a particular focus on chiropractic and family physician teams in primary care settings (Boon, Mior, Barnsley, Ashbury, & Haig, 2009).

Many topics related to implementation can be seen as sensitive, and personal interviews were seen as the best way to acquire in-depth and candid information in a short period of time. These interviews were conducted on a one to one basis which allowed the interviewees to express their opinions freely, without the conflict that may arise from a group setting (UCLA Center for Health Policy Research, 2012)

To understand the progress of the Jeddah dengue Control Strategies it was necessary to conduct personal interviews with people working in the Ministry of Health, Ministry of Agriculture, and the Jeddah Municipality. Some of these people had themselves published work on dengue fever in Jeddah City. Interviewing them provided an opportunity to gain additional insights that were not included in Government documents. Only by an interview was it possible to get detailed and rich data in a practical and inexpensive way. Furthermore, these interviews provided an opportunity to build relationships with important officials working on dengue fever (UCLA Center for Health Policy Research, 2012). All data were used to assess the strategic response and provide answers to questions not available from a quantitative approach.

Ethical approval for this low-risk research was received from the University of Canterbury Human Ethics Committee (Ref: HEC 2012/23/LR-PS), (Appendix 2**)**. The Committee granted a waiver so that the interviewees were not required to sign the consent form if they preferred not to. The rationale was because it was thought that cultural factors, such as having a fear of their confidentiality being breached, or being seen to criticise authority, might have prevented the interviewees from signing the form (and therefore from providing information). If an interviewee did not wish to sign the consent form, the researcher was permitted to do the interview with a note (signed by the researcher) made on the consent form to show that the conversation had been held with verbal consent given.

Selection of sample

The size of any sample depends on the purpose and scope of the study and, although there is no real consensus on the optimal sample size, the goal is “data saturation” (Suzuki, Ahluwalia, Arora, & Mattis, 2007). Because of time constraints and limited access to potential interviewees, only 15 interviews were conducted for this doctoral research. Although this might be considered a sufficient number to achieve data saturation, it had initially been hoped that there would have been a larger sample of interviews to ensure that saturation was achieved. The 15 interviewees comprised people from Jeddah City Municipality, the Ministry of Health and the Ministry of Agriculture. Interviewees were chosen because of their knowledge of, or involvement in, the dengue fever Control Strategies for Jeddah City. Selecting the interviewees involves purposeful sampling where individuals are identified for their knowledge and experience (Palinkas et al., 2013). The sample included people from all levels of policy and project leadership as well as those working in the field. The goal was to acquire more information and detail about the implementation status of the Control Strategies and the plans for future action.

The 15 people fell into three categories. In the first group were employees of the Jeddah Municipality who were selected because of their intimate knowledge of all the dengue control projects. Some were involved in more than one of these projects but not everyone in this group still worked for the Jeddah City Municipality. The second group of interviewees were from the Ministry of Health, including personnel working in Jeddah City. The third group comprised people from the Ministry of Agriculture who worked outside the Jeddah City limits. Some of the interviewees had been involved in dengue fever projects in 2006, before the Saudi Government announced a new programme of projects.

Recruitment

In recruiting for this research, it was intended that each person be interviewed separately, face to face for about one hour in either Jeddah City or Riyadh. Interviewees were identified through the researcher's personal contacts and other knowledge of dengue control activity. The potential interviewees were contacted by telephone to arrange a meeting and were provided with the project information sheet (Appendix 3), and details for consent (Appendix 4). The researcher met 13 interviewees face to face, and 11 of those were able to be interviewed at their work place; however, two of them chose to meet in a coffee shop. One interviewee was not happy to do the interview at his work because he did not want anyone to witness him being interviewed, so he asked to go out for coffee. Most interviewees were happy to have the meeting recorded, but some did not want that and said that taking notes was sufficient. Initially, all of the 13 interviewees sought the waiver of written consent as approved by the University of Canterbury Ethics Committee (Appendix 2). After the interview had finished, six interviewees asked to sign the formal consent form because they were no longer worried about the questions nor the interview process. Two interviewees out of 15 were not in Saudi Arabia. One interview was conducted by Skype and the second by telephone, and both of them had asked for a waiver of written consent before the interview.

Data collection

Typically qualitative descriptive studies use semi-structured interviews to collect the data, for two reasons. First, interviewees can give greater detail in relation to their perceptions and opinions on sensitive issues and provide clarification of answers when probed by the researcher. Second, there are a number of contexts, for example when interviewing a range of staff who have different roles within an organisation, where structured (or standardised) questions are precluded because responsibilities, knowledge, and roles differ (Barriball & While, 1994; Baumbusch, 2010; Drever, 1995; Kajornboon, 2005; Longhurst, 2003). As an example, Barribal and While (1994) reported that standardised interviews were not appropriate for their research project with nurses because of their diverse personal and professional backgrounds (Barriball & While, 1994). In a paper on using interviews as research instruments, Kajornboon, (2005), notes that "the strengths of semi-structured interviews are that the researcher can prompt and probe deeper into the given situation" (p.5).

Semi-structured interviews do not necessarily use a standardised set of questions, and are not used to test a specific hypothesis (David & Sutton, 2004). Instead of a pre-set hypothesis the researcher looks for themes and issues that arise, in part, from answers to the questions posed. For this reason, in a semi-structured interview the questions may change depending on the way of the interview is progressing (Corbetta, 2003).

All the interviews in this doctoral research were semi-structured using key questions to guide the interviewees towards the types of information sought, and to encourage detailed responses. There were variations in questions asked depending on the role of the informant. The Control Strategies' document for dengue fever in Jeddah City, informed the development of some questions. Seven main questions were put to the interviewees:

1. What is your job, and what role does it play in controlling Dengue fever? What are the strategic and operational functions of your job?
2. Can you explain what you know about dengue fever and whether other cities in Saudi Arabia have the same problems?
3. Are you aware of the differences in numbers of cases across Jeddah City and the reasons for these differences?
4. Do you think there is enough support for dengue control from the Government as well as the Ministry of Health/ Jeddah Municipality?
5. How well do the various control agencies work together?
6. How well are the Control Strategies being implemented? Is this satisfactory or is there a need for improvement?

7. Do you have any recommendations for controlling dengue fever in Jeddah?

Most of the interviews (14) were in Arabic with only one in English. Approximately one hour was allocated for each interview. Questions were also included on the interviewees background and the qualifications for their position, their knowledge about dengue fever in Saudi Arabia and Jeddah City, a description of dengue fever in Jeddah City, seasonal variation, the operational levels of their job, the relationship between the Government departments, and any recommendations the person may have.

All were asked the same core questions with some asked additional questions relevant to their area of expertise. There was clarification of some of the questions and follow-up questions to avoid yes or no answers and achieve the maximum information. For example, Jeddah Municipality had 11 control projects, and those working on particular projects had questions specific to those projects in addition to the general standard questions. Interviews were not transcribed, but detailed notes were made from the recordings, and the recordings reviewed several times to elaborate on the notes.

Thematic Analysis

There are two broad approaches to thematic analysis: deductive (or pre-determined) and inductive (emergent). A deductive approach uses prior theory or assumptions to guide the analysis whereas an inductive approach to analysis allows the data to generate categories and themes (Elo & Kyngäs, 2008; Teddlie & Tashakkori, 2009; D. R. Thomas, 2006). For this research both deductive and inductive approaches were used. A number of themes had been identified as of importance and on the basis of these a number of questions were included in the interview guide. Other categories of data that had not initially been anticipated arose in the course of the interviews and these contributed to other themes or sub-themes. The interview data were analysed under themes and subthemes which represented the interviewees' understanding of, and views on, particular aspects of dengue control. All data were anonymised with respondents assigned a number from 1 to 15 so that confidentiality was maintained in reporting. In thematic analysis, meanings and patterns of themes are identified before, during, and after the analysis. As recommended by Braun and Clarke (2006), all data obtained from the interviews were examined to determine if any repeated patterns arose. If themes were found, they were reviewed, defined and named so that the final report could fully reflect the content of the interviews.

Clarification was often able to be achieved using documentary resources. The final descriptive analysis therefore used two sources of data: all the Government documentary data that were available, and the interview data that were analysed. The Government documentary data helped the researcher to understand the Jeddah City dengue fever control projects as reported by respondents.

As suggested by Thomas (2006), information from all the interviewees was collated, and several re-readings of notes and recordings undertaken to identify similarities across the data and assemble these into categories of information (Thomas, 2006). The information categories were compiled into main themes for reporting the qualitative analysis. Some of these main themes included more specific information which could then be developed as sub-themes. After the main and sub-themes were identified, further reading of the interviews took place to ensure all linkages between them had been identified.

Rigour in Qualitative Research

The standard of rigour in qualitative research helps to ensure that the research is thorough and accurate (Milne & Oberle, 2005; Murphy & Yielder, 2010; E. Thomas & Magilvy, 2011). This qualitative research was designed to incorporate the four criteria set out by Thomas and Magilvy, (2011): (1) credibility (2) transferability (3) dependability and (4) confirmability (E. Thomas & Magilvy, 2011).

Credibility has an important role in allowing others to recognize the experiences of the participants who contributed their knowledge towards the research study (E. Thomas & Magilvy, 2011). The researcher takes the opportunity to ask peers or consultants who have experience in qualitative research to review and discuss the coding process (Holloway, 1997). In this case the outcomes from the themes analysis were reviewed by the thesis supervisors. Moreover, time spent with the participants, the careful interview methods, and the use of quotations from the participants are considered strategies that give the research more credibility (Murphy & Yielder, 2010; E. Thomas & Magilvy, 2011). Credible research is directly connected with such efforts to establish research validity and reliability (Golafshani, 2003).

Transferability refers to the capability to transfer findings or methods of research from one group to another so that it is applicable in other contexts or to other participants (E. Thomas & Magilvy, 2011). One method to establish transferability is to provide a complete description of the population studied and its setting, including descriptions of both demographic and geographic limitations of the study (Murphy & Yielder, 2010; E. Thomas & Usher, 2009). The qualitative methods set out here aim to provide clear descriptions of each stage of the study, through data collection and analysis to the discussion of the results which makes it possible to replicate this approach in any future study of dengue fever control.

Dependability is closely connected to transferability. It occurs when another researcher can follow the direction of the researcher's decision-making. This path can be established by describing the specific purpose of the study, discussing the process of selecting the participants, explaining how the data were collected, and the time it took to get the information (Milne & Oberle, 2005; E. Thomas & Magilvy, 2011). In this research it is made clear that the evaluation of dengue fever Strategies was the main purpose of the interviews, and that the selected interviewees, although they are working in different areas, had the expertise to comment on the Control Strategies. The time taken to interview the 15 participants (three months) gave the interviewer time to understand and reflect on the information received, and the subsequent thematic analysis provided the opportunity to create a full and dependable narrative based on this information.

The final objective of rigour is **confirmability,** which is similar to objectivity in quantitative research. It can be achieved when credibility, transferability and dependability have all been established. Reflexivity is also involved in that the researcher has a self-critical attitude to any personal preconception that may affect the research. After the interviews, audio-tapes provide a record of the field notes regarding the researcher's personal feelings and perceptions (Milne & Oberle, 2005; E. Thomas & Magilvy, 2011). In this research, the qualitative analysis was open to any level of information from the interviewees that allowed wide ranging commentary which could be applied across the different levels of the analysis and covering a number of perspectives on how the dengue fever Strategies were implemented in Jeddah City.

4.4 Conclusion

This chapter has explained how qualitative and quantitative methods were applied in a concurrent mixed methods approach to examine all the research questions and analyse the three research objectives. The main data sources come from the Government sources and from interviews with people working in dengue fever projects. The next two chapters present the results: Chapter 5 contains the analysis of the quantitative data and Chapter 6 the analysis of the qualitative data.

Chapter 5: Spatial and Temporal Distribution and Neighbourhood Explanatory Factors of Dengue Fever in Jeddah City

5.1 Introduction

The aim of this chapter is to investigate and analyse the spatial and temporal distribution of dengue fever cases in Jeddah City, Saudi Arabia, and their relationship to neighbourhood social and physical environmental factors. Chapter 3 discussed dengue fever in Saudi Arabia more generally and found that Jeddah City has the highest concentration of documented cases in Saudi Arabia. This chapter will answer the following questions:

1. What is the spatial distribution of dengue fever in Jeddah City's neighbourhoods?
2. To what extent is there evidence of spatial and temporal clustering of dengue fever cases?
3. What types of neighbourhood explanatory variables are important for the spatial distribution of dengue?
4. What effects do climate factors have on dengue fever case rates and to what extent are seasonal variations in dengue are related to neighbourhood social conditions?

This chapter is comprised of four sections. The first section investigates the spatial distribution of dengue fever in Jeddah City's neighbourhoods between 2006 and 2009. This is followed by analysis of the extent to which dengue fever cases are clustered in certain types of neighbourhoods. In addition, spatio-temporal trends in dengue fever cases are examined on a weekly basis to understand how the distribution of dengue fever in Jeddah City neighbourhoods changed following major outbreaks.

The third section considers the importance of neighbourhood physical and social environmental factors as explanations for the distribution of dengue fever. Particular attention is paid to the direct influence of socioeconomic variables in explaining the rate of dengue fever cases, but also to the indirect impacts of other demographic factors, such as the presence of a large number of non-Saudi migrants and population density. Also examined are water drainage issues, in terms of the presence of surface water and the extent to which their neighbourhood location has affected the increasing number of dengue fever cases.

The final section examines the influence of climate conditions and their relationship to temporal variations in the numbers of dengue fever cases. Such variations are also related to neighbourhood socioeconomic status in order to determine the extent to which the temporal variation in dengue fever cases was most pronounced in certain types of neighbourhoods.

5.2 Dengue in Jeddah City by neighbourhood

Official census data for Jeddah City neighbourhoods is only available from the Central Department of Statistics and Information for 2004. The next census in 2010 only provides total population data for Jeddah City, but not data at the neighbourhood level (Central Department of Statistics & Information, 2011). The Jeddah Urban Observatory in Jeddah Municipality has estimated the population of Jeddah City neighbourhoods in 2009 (Jeddah Municipality, 2010). The census data for 2004 and the population estimates for 2009 were used to estimate neighbourhood populations between those years. After matching all dengue fever data from 2006 to 2009 with the neighbourhoods, there were 56 neighbourhoods for which census data was available. These neighbourhoods contained 74.7% all dengue fever cases in 2006, 65.8% in 2007, 75.8% in 2008 and 63.6% in 2009. This information was used for this section and all the spatial analyses in this chapter.

Figure 5.1 shows the locations of the low, mid and high socioeconomic neighbourhoods in Jeddah City and the name of the neighbourhoods and the number of dengue fever cases which corresponds to table 5.1. Table 5.1 presents the number of dengue fever cases from 2006 to 2009 in Jeddah City by neighbourhood. For some neighbourhoods, such as Al Basateen, a more affluent part of Jeddah City, the number of cases, while high in 2006, has decreased each year. Another example is Al Nuzha neighbourhood, which had 45 cases in 2006 and then decreased to 16 in 2009. On the other hand, low socioeconomic status neighbourhoods showed there were some areas that had a marked increase in the number of cases while others experienced no change or a decrease.

Al Azizeiah neighbourhood, for example, had only one case in 2006 but 48 cases by 2009. By contrast Al Sabeel, another low socioeconomic status neighbourhood, had 71 cases in 2006 but only 7 by 2009 (Ministry of Health, 2010). Most of the dengue fever cases in Jeddah City between 2006-2009 were located in low socioeconomic status neighbourhoods with 74.5% cases, while the mid socioeconomic status neighbourhoods had 19.2% cases and high socioeconomic status neighbourhoods had 6.3% cases.

The high share of cases found in low socioeconomic status neighbourhoods remained relatively unchanged over the four years ranging from a low of 68.8% cases in 2006 to high of 78.6% in 2007. Across all neighbourhoods the number of cases was 976 in 2006, dropping to 160 in 2007; however, the number then steadily rose again to 612 in 2008 and to 1,021 in 2009. Compared to the low point in 2007, the number of cases increased nearly fourfold (3.9) in high status neighbourhoods, nearly fivefold (4.9) in middle status neighbourhoods and nearly sixfold (5.7) in low status neighbourhoods, but high status neighbourhoods were the only areas to record fewer cases in 2009 compared to 2006.

Table 5.2 shows neighbourhood variations in the number of dengue fever cases and the rate per 10,000 people for the 56 neighbourhoods in Jeddah City grouped by neighbourhood socioeconomic status. Low socioeconomic status neighbourhoods had the highest average number of cases, being 3.95 times that of high status neighbourhoods for the period 2006-2009. Social differences in the number of cases, as measured by the ratio of the average number of cases in high compared to low socioeconomic status neighbourhoods, were greatest in 2008, but also high in 2009. While low socioeconomic status neighbourhoods had the highest average number of cases, the high standard deviations nevertheless indicate that substantial variations existed even among low status areas. As expected, the standard deviations for the number of cases are higher than those for case rates. With the exception of 2006, internal neighbourhood differences, regardless of socioeconomic status, in the number of cases and case rates tended to increase over time.

Neighbourhood variations in rates of dengue fever also show some social patterning, but are much less marked when compared to variations in the average number of cases. When actual rates are compared between low and high status neighbourhoods the social gap in case rates also occurred in high status neighbourhoods. Individual neighbourhood variations are shown in Appendix 5. The reason for the high number and rate of dengue fever cases in the low socioeconomic status neighbourhoods reflects a number of factors including poorer environmental conditions, large numbers of migrant people, high population densities and poor lifestyles. These factors are also conducive to the rapid spread of dengue fever cases in Jeddah City neighbourhoods.

As shown in Figure 5.2, the areas with the highest average number of dengue fever cases per 10,000 people from 2006 to 2009 are located in the city centre of Jeddah City and in south of Jeddah which is a less affluent part of the city (Ministry of Health, 2010). There is only one neighbourhood with a high rate of dengue fever cases that is located outside of Jeddah City centre and south Jeddah City; this is Obhur Al Shamaliah, a high status neighbourhood of low population density (Jeddah Municipality, 2012; Ministry of Health, 2010).

The first outbreak of dengue fever in Jeddah City in 2006 is depicted in Figure 5.3. The neighbourhoods with the largest number of dengue fever cases per 10,000 people can be seen in the city centre and north of the city. The highest rate of dengue fever cases was in the centre of the city, but in 2007 there was also a high rate of dengue fever cases north and south of the city centre (Figure 5.4). The years 2006 and 2007 had almost the same distribution of dengue fever in Jeddah City. In 2008, there was a high rate of dengue fever cases in the city centre and in one neighbourhood to the south of the city centre (Figure 5.5), but by 2009 there was also evidence of dengue spreading into neighbourhoods north of the city centre (Figure 5.6) (Jeddah Municipality, 2012; Ministry of Health, 2010).

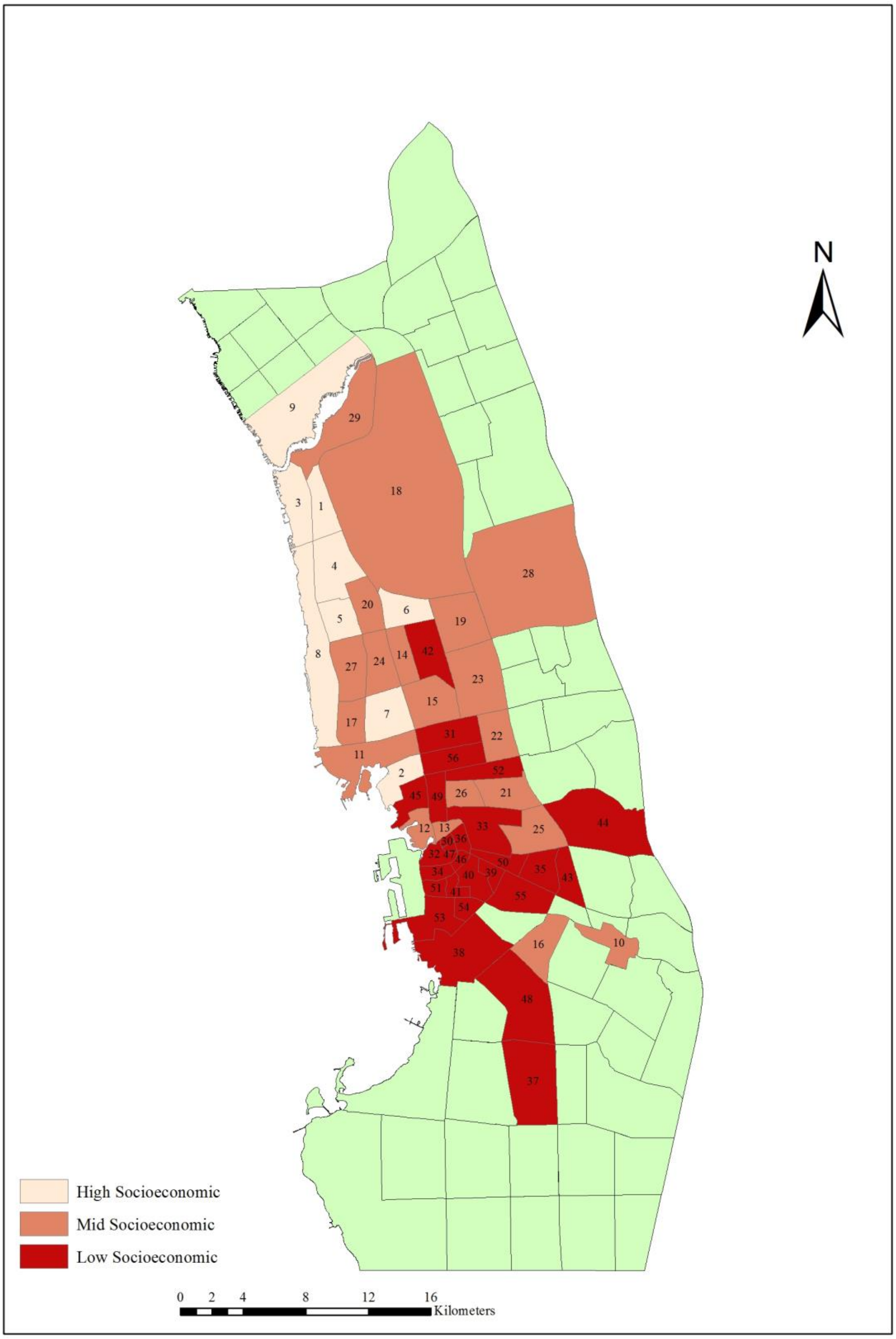

Figure 5.1 Socioeconomic status neighbourhoods in Jeddah City

Table 5.1 Number of dengue fever cases and socioeconomic status (SES) in Jeddah City neighbourhoods, 2006-2009

ID	Neighbourhoods	2006	2007	2008	2009	Total	SES level
1	Al Basateen	36	2	1	2	41	High
2	Al Hamrah	4	2	0	12	18	High
3	Al Marjan	0	0	1	1	2	High
4	Al Mohammadeiah	2	1	1	1	5	High
5	Al Nahdah	1	1	3	4	9	High
6	Al Nuzha	45	1	3	16	65	High
7	Al Rawdah	5	2	4	11	22	High
8	Al Shate	4	0	1	0	5	High
9	Obhur al shamaliah	4	1	0	2	7	High
Total High SES		**101**	**10**	**14**	**49**	**174 (6.3%)**	
10	Al Ameerfawaz	6	1	9	20	36	Mid
11	Al Andulus	17	0	1	1	19	Mid
12	Al Bagdadeiah al garbeiah	15	1	21	5	42	Mid
13	Al Bagdadeiah al sharqeiah	1	0	24	14	39	Mid
14	Al Bawadi	3	6	9	28	46	Mid
15	Al Faysaleiah	3	6	4	18	31	Mid
16	Al Jawharah	0	0	1	1	2	Mid
17	Al Khalediah	1	3	2	4	10	Mid
18	Al Malekabdoulazez airport	0	0	0	0	0	Mid
19	Al Marwah	12	2	4	19	37	Mid
20	Al Naeem	3	1	3	8	15	Mid
21	Al Naseem	11	2	7	10	30	Mid
22	Al Rehab	18	1	2	11	32	Mid
23	Al Safa	25	13	20	67	125	Mid
24	Al Salamah	2	2	2	8	14	Mid
25	Al Sulaymaneiah	12	1	4	9	26	Mid
26	Al Worood	0	0	1	0	1	Mid
27	Al Zahra	3	1	1	3	8	Mid
28	Buraiman	8	0	2	8	18	Mid
29	Obhur al janoubeiah	1	0	0	0	1	Mid
Total Mid SES		**141**	**40**	**117**	**234**	**532 (19.2%)**	
30	Al Ammareih	1	3	20	8	32	Low
31	Al Azizeiah	1	17	28	48	94	Low
32	Al Balad	9	5	35	26	75	Low
33	Al Fiha	1	1	4	3	9	Low
34	Al Hendaweiah	50	12	61	34	157	Low
35	Al Jameah	95	8	54	101	258	Low
36	Al Kandarah	21	4	52	26	103	Low
37	Al Khomrah	6	1	4	9	20	Low

38	Al Mahgar	25	1	6	23	55	Low
39	Al Nazlah al sharqeiah	64	1	0	8	73	Low
40	Al Nazlah al yamaneiah	13	5	7	30	55	Low
41	Al Qryat	21	1	19	33	74	Low
42	Al Rabwah	25	15	9	45	94	Low
43	Al Rawabe	8	6	15	49	78	Low
44	Al Rughamah	9	2	6	22	39	Low
45	Al Ruwase	33	1	8	12	54	Low
46	Al Sabeel	71	1	27	7	106	Low
47	Al Sahefah	11	6	18	7	42	Low
48	Al Senaeya	0	1	2	4	7	Low
49	Al Sharafiah	14	7	18	28	67	Low
50	Al Thagur	12	2	13	12	39	Low
51	Al Thalebah	17	0	13	11	41	Low
52	Bane malek	18	2	7	23	50	Low
53	Betrumeen	43	1	12	27	83	Low
54	Guleel	127	5	31	88	251	Low
55	Madaen al fahad	36	2	8	42	88	Low
56	Meshrefah	3	0	4	12	19	Low
Total Low SES		**734**	**110**	**481**	**738**	**2063 (74.5%)**	
Overall Total		**976**	**160**	**612**	**1021**	**2769 (100%)**	

Source: (Ministry of Health, 2010)

Table 5.2 Number of dengue fever cases and case rate per 10,000 people by neighbourhood socioeconomic statues, Jeddah City, 2006–2009

Year	**Mean**			**Standard Deviation**		
	High SES	**Mid SES**	**Low SES**	**High SES**	**Mid SES**	**Low SES**
Cases, 2006	11.2	7.0	**27.2**	16.8	7.3	30.8
Cases, 2007	1.1	2.00	**4.0**	0.8	3.1	4.5
Cases, 2008	1.6	5.8	**17.8**	1.4	7.3	16.4
Cases, 2009	5.4	11.7	**27.3**	5.9	15.1	23.8
Average Cases, 2006-2009	4.8	6.6	**19.1**	5.2	6.9	15.3
Rate cases, 2006	6.2	2.4	**6.5**	11.5	3.2	7.5
Rate cases, 2007	0.7	0.3	**1.2**	0.9	0.4	2.4
Rate cases, 2008	0.5	1.9	**4.7**	0.4	3.6	5.3
Rate cases, 2009	6.0	3.1	**6.7**	8.3	7.1	9.2
Average rate cases, 2006-2009	3.4	1.9	**4.8**	4.7	3.9	4.5

Source: (Ministry of Health, 2010)

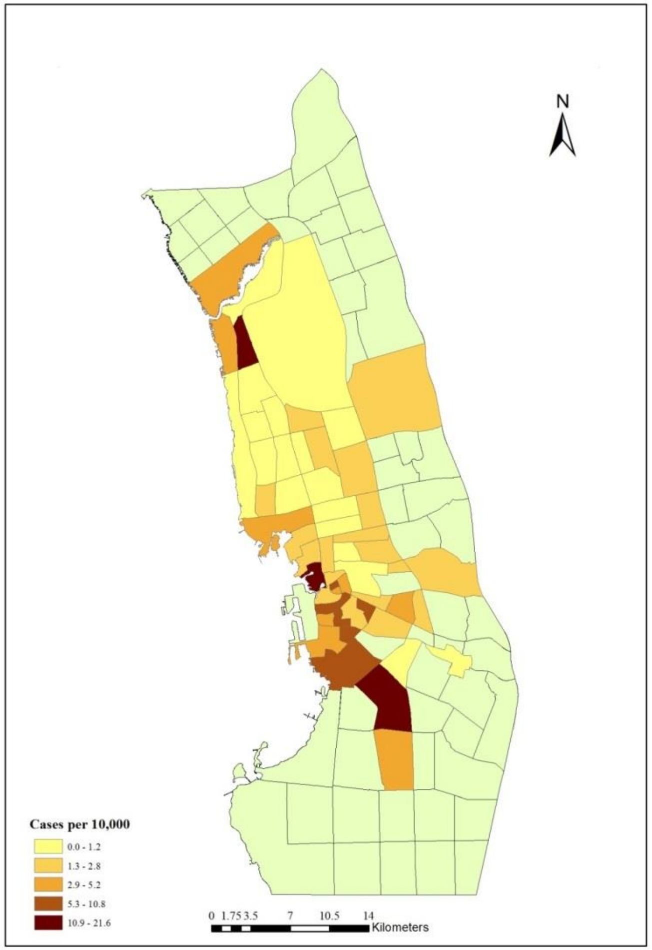

Figure 5.2 Average dengue fever cases per 10,000 people in Jeddah City, 2006-2009

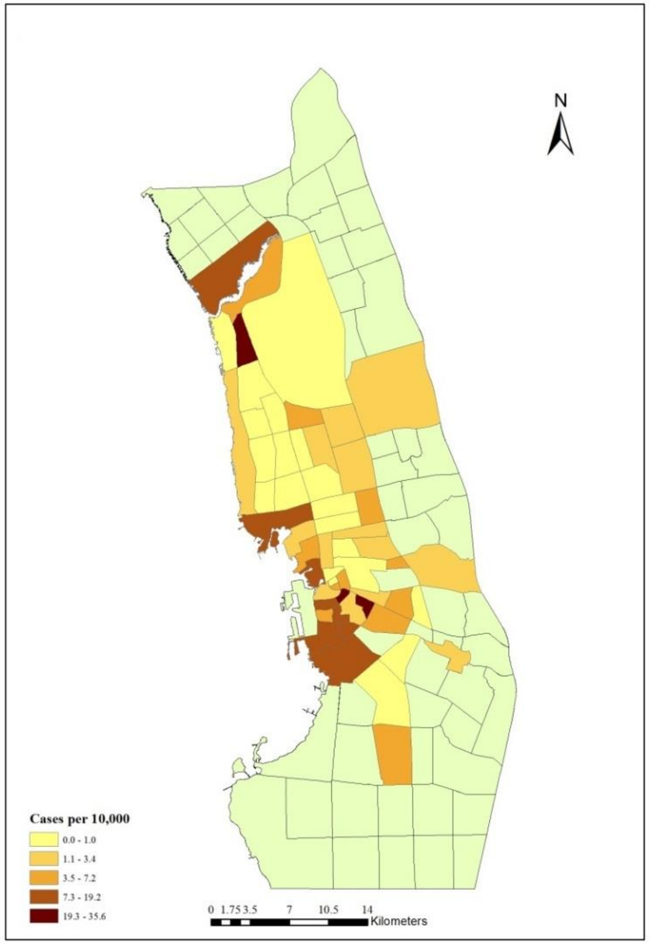

Figure 5.3 Dengue fever cases per 10,000 people in Jeddah City, 2006

Sources: (Jeddah Municipality, 2012; Ministry of Health, 2010)

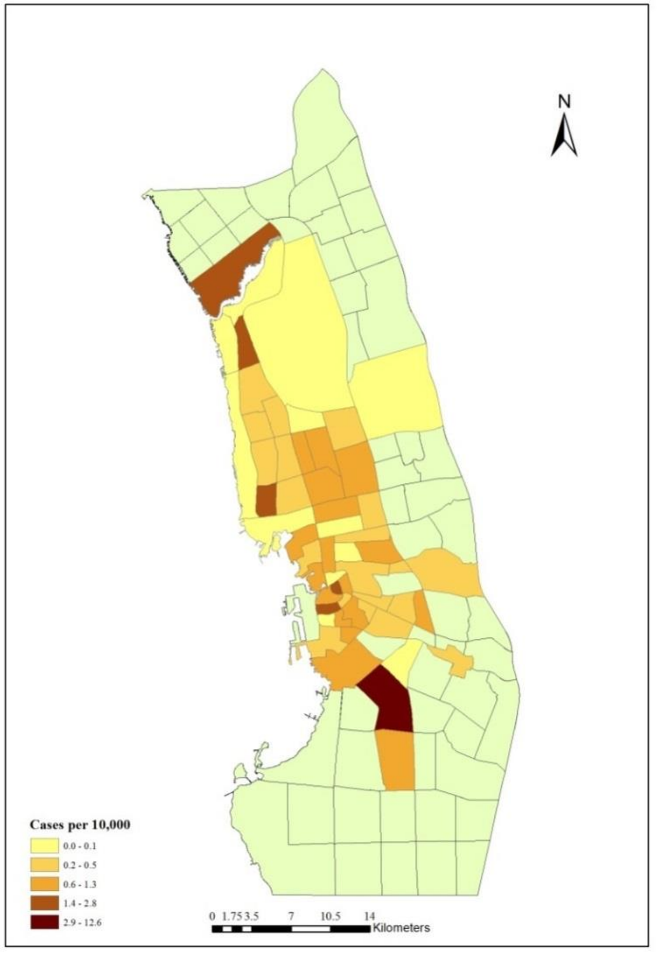

Figure 5.4 Dengue fever cases per 10,000 people in Jeddah City, 2007

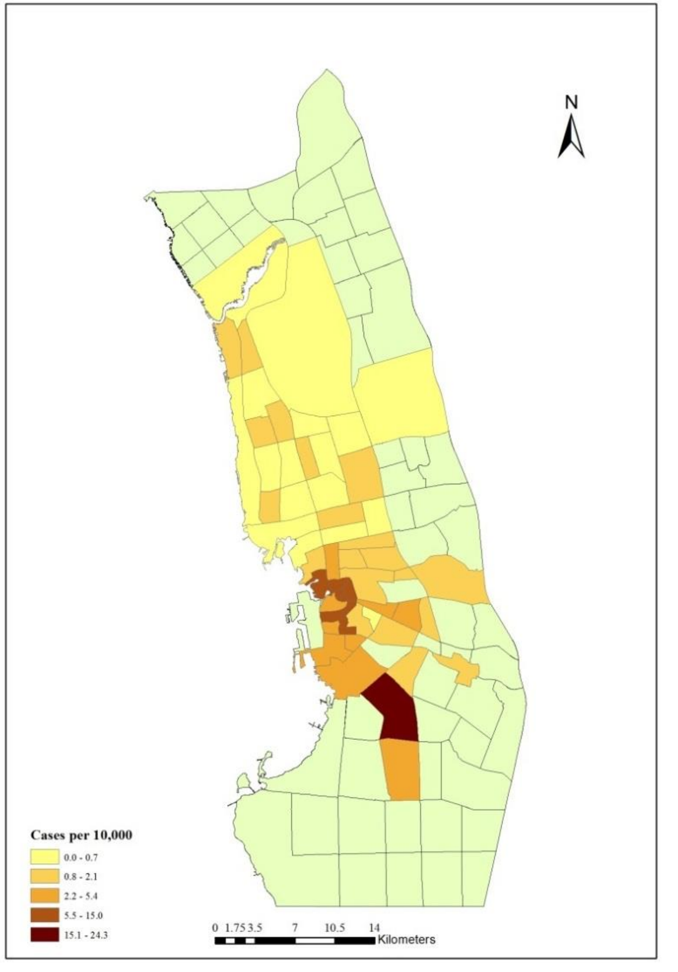

Figure 5.5 Dengue fever cases per 10,000 people in Jeddah City, 2008

Sources: (Jeddah Municipality, 2012; Ministry of Health, 2010)

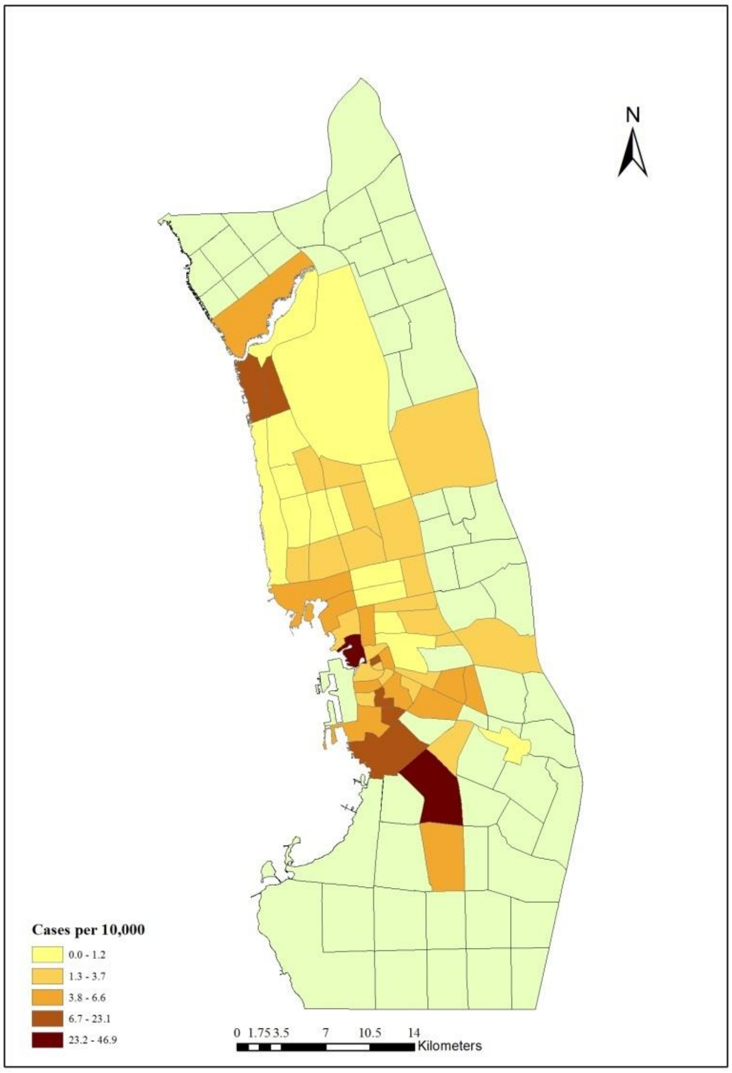

Figure 5.6 Dengue fever cases per 10,000 people in Jeddah City, 2009

Sources: (Jeddah Municipality, 2012; Ministry of Health, 2010)

5.3 Hot spot and spatio-temporal analysis of dengue fever cases in Jeddah City neighbourhoods

This section analyses dengue fever cases in Jeddah City neighbourhoods using two different spatial measurements: hot spot analysis, and the degree of spatial spread of dengue following the major peak weeks of dengue fever cases. These two measurements were used to analyse the extent to which there was a significant clustering of dengue fever cases and evidence of them spreading spatially after major outbreaks.

5.3.1 Hot spot analysis

Hot spot analysis was used to calculate the Getis-OrdGi statistic for each feature in the dataset context of the neighbouring features to indicate the high and low spatial clusters of hot spots of dengue fever in Jeddah City neighbourhoods. The neighbourhoods with high *z*-scores and *p*-values of significance indicate high spatial clusters of hot spots, while the neighbourhoods with low *z*-scores and *p*-values of significance indicate low spatial clusters of hot spots.

Figure 5.7 indicates the high and low spatial clusters of hot spots for the average rate of dengue fever cases per 10,000 people in Jeddah City neighbourhoods from 2006-2009. The results of the hot spot analysis show that the high hot spots are concentrated in the central core and the low hot spots are in the north Jeddah City neighbourhoods. The highest hot spot neighbourhood is Al Mahgar neighbourhood, which has the highest *z*-score of 3.11 and $p < 0.00$ with a total number of dengue fever cases at 55 and an average rate of 10 dengue fever cases per 10,000 people. For the lowest hot spot neighbourhoods, the cluster was located in Al Bawadi neighbourhood with a *z*-score of -2.50 and $p < 0.00$ with a total of 46 dengue fever cases, and an average rate of 0.6 dengue fever cases per 10,000 people. The socioeconomic status for Al Mahgar neighbourhood was low while Al Bawadi neighbourhood was a middle status neighbourhood.

To provide a greater understanding of the neighbourhood characteristics of the high and low hot spots, the profiles of both are shown in Table 5.3. The average number of cases and the average rate of cases per 10,000 people from 2006 to 2009, including population density in 2009, the Saudi sex ratio (males per 100 females) in 2004, the non-Saudi sex ratio in 2004, the percentage of low socioeconomic status in 2013 and percentage of non- Saudi population in 2004 had a higher mean and standard deviation in the high hot spots than in the low hot spots.

There were a number of reasons for the above factors being related to the hot spots of dengue fever in Jeddah City neighbourhoods. High population density as a variable contributed to the spread of dengue fever cases in neighbourhoods because the *Aedes* mosquito, that transmits the dengue virus, can do so more quickly in areas where people live closer together. That fact that there were more dengue fever cases for males than females in both Saudi and non-Saudi populations in the high hot spot neighbourhoods, may be because women do not travel outside their homes as much as men. This is partly because women are not allowed to drive in Saudi Arabia, but also because most of the non-Saudi people living in Jeddah City are male workers. There is a strong correlation, however, between the lower socioeconomic status neighbourhoods and high hot spots, which reflects the poorer living and environmental conditions which contribute to the higher rates of dengue fever can be found there. The percentage of non-Saudi people was also higher in high hot spots, compared to the low hot spots, suggesting that non-Saudi people were more likely located in lower socioeconomic neighbourhoods.

The above analysis thus provides some evidence for a positive correlation between dengue case rates and neighbourhood population density, Saudi and non-Saudi sex ratios, the percentage of non-Saudi people and socioeconomic factors. These population characteristics are investigated in more detail in section 5.4.

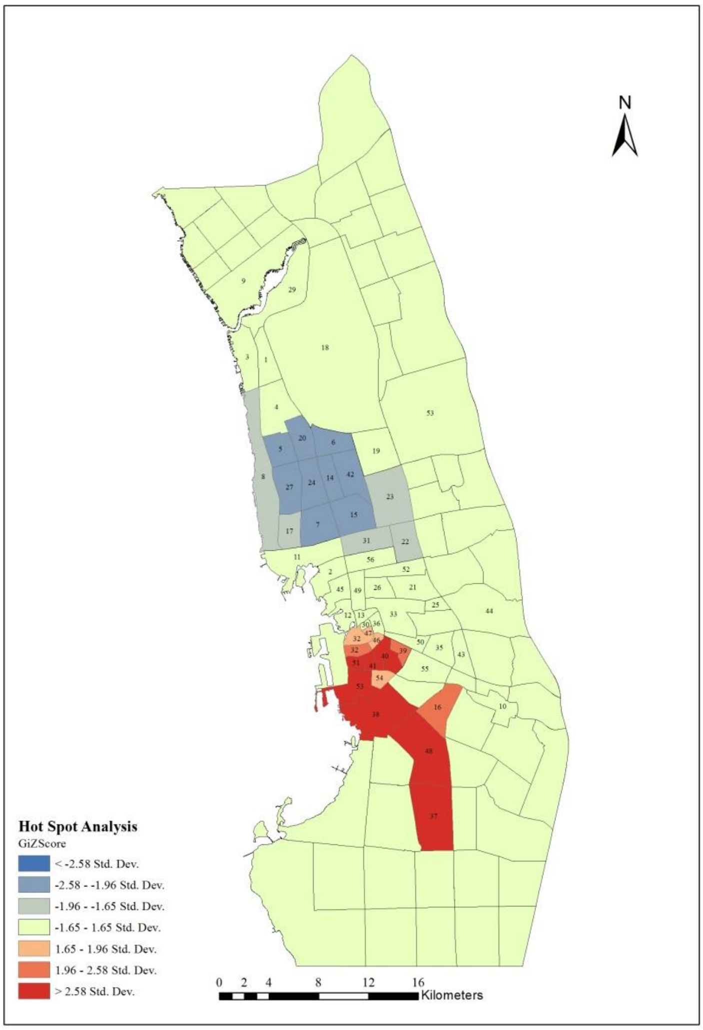

Figure 5.7 Dengue fever hot spot analysis in Jeddah City (Average rate per 10,000 from 2006 to 2009)

Sources: (Jeddah Municipality, 2012; Ministry of Health, 2010)

Table 5.3 Demographic characteristics of dengue fever cases in the high and low hot spots

Neighbourhood Characteristics	High Hot Spot		Low Hot Spot	
	Mean	STDEV	Mean	STDEV*
Average cases 2006-2009	13.9	13.5	10.8	13.0
Average rate cases per 10,000 for 2006-2009	5.6	5.1	1.5	1.0
Population density, 2009	15473	14870	10745	8340
Sex ratio Saudi males per 100 females, 2004	279	847	111	18
Sex ratio non-Saudi males per 100 females, 2004	1449	6253	237	197
% non-Saudi people, 2004	63.2%	22.7%	45.5%	18.7%
% Low socioeconomic level, 2013	68.0%	31.8%	25.0%	22.9%

*Standard deviation

5.3.2 Time lag on the major peak week of dengue fever in Jeddah City neighbourhoods

Whilst the analysis described above indicated the location of hot spots of dengue fever cases in Jeddah City neighbourhoods it did not examine spatio-temporal trends on a weekly basis, and this, therefore, is the objective of this section. Since the outbreak of dengue fever in Jeddah City in 2006, there have been weeks when the numbers of dengue fever cases have peaked to very high levels in certain Jeddah City neighbourhoods. The question arises of whether there was any evidence of a spatial spread of dengue fever away from the hot spots (after the major peak week) that developed. Because only 160 cases of dengue fever were reported in 2007, this analysis is restricted to 2006 and 2008-2009.

Figure 5.8 shows the neighbourhood (Guleel) with the largest weekly number of cases in 2006 and the subsequent number of cases in the following three weeks, covering the period weeks 16-19 (April-May). In week 16, the major peak week, the Guleel neighbourhood, a poorer high density area located in the centre of Jeddah City, had 16 dengue fever cases. In the following week (in April), the closest neighbourhoods to the east and the north showed more cases. Week 18 (in May) showed the neighbourhoods located to the east of Guleel neighbourhood developed into a hot spot more than anywhere else in Jeddah City. There are two new neighbourhoods in week 19 (May) to the west and south of the Guleel neighbourhood each with a high number of dengue fever cases, but to the north there are fewer cases than in the previous week.

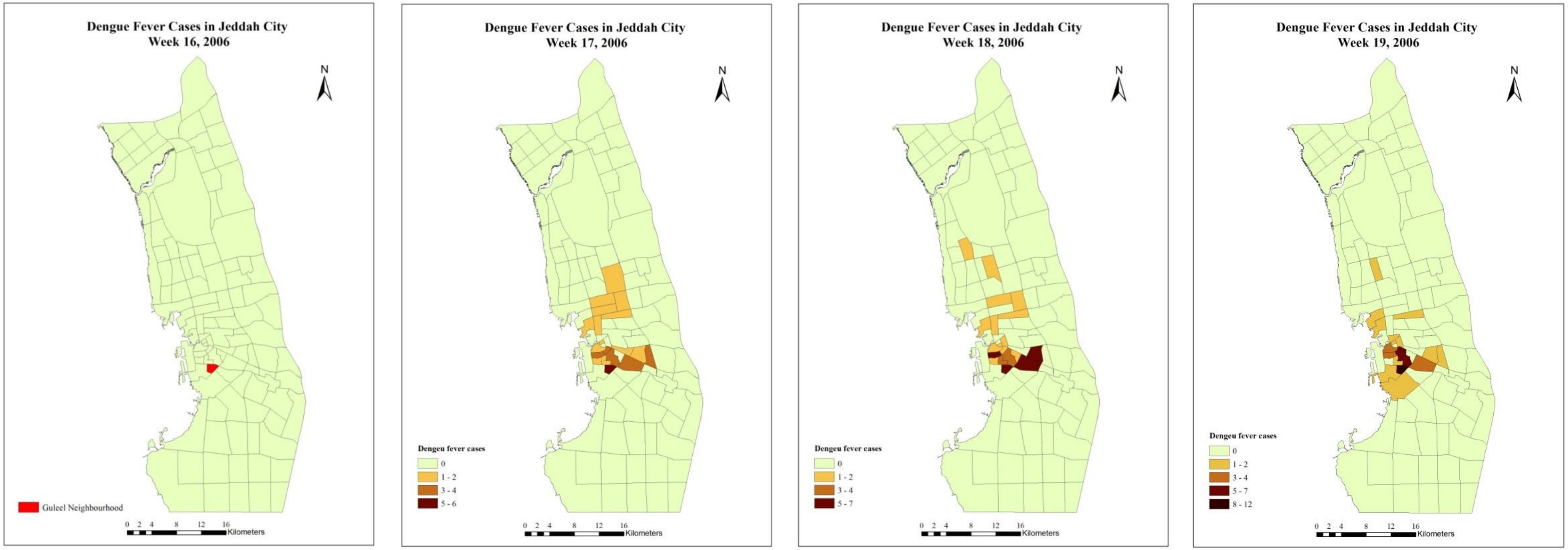

Figure 5.8 Dengue fever lag time weeks in Jeddah City (Weeks 16-19, Spring and Summer seasons), 2006

Sources: (Jeddah Municipality, 2012; Ministry of Health, 2010)

Figure 5.9 shows the major peak week for dengue fever cases in 2008 and the number of cases recorded in the following three weeks in Jeddah City neighbourhoods during the summer season. Al Jameah neighbourhood recorded the greatest number of weekly cases (10) in week 21 (May). In the following week a cluster of neighbourhoods to the south of Jeddah City had the largest number of cases but this did not persist over the next two weeks (week 23 and week 24 in June). Instead new neighbourhoods on the east side of Jeddah City were affected during those weeks.

In 2009 the Al Jameah neighbourhood also recorded the largest weekly peak of dengue fever cases (10 cases), but the week is different. For 2009, Figure 5.10 shows dengue fever cases in Jeddah City neighbourhoods in the three subsequent weeks in the summer season. The major peak week for 2009 is week 27 (in July) and the following week showed the cluster in the south appearing again, plus one more new case in the north close to the hot spot neighbourhood in the east of that cluster. The centre of the city seems to have strong neighbourhood clusters with two hot spot neighbourhoods. In the next two weeks in July, dengue fever cases spread from the north to the south of Jeddah City, and Al Jameah neighbourhood continued to remain as a hot spot in Jeddah City. By week 30 (July), however, Al Jameah neighbourhood was no longer a hot spot with a new hot spot emerging to the north.

To consider the question as to whether there was evidence of a spatial spread of dengue fever away from neighbourhoods that recorded the largest number of weekly cases, the results from 2006 to 2009 of the major peak week of dengue fever cases in Jeddah City neighbourhoods suggest that there was indeed spatial spread. In 2006 and 2007 the major peak neighbourhood (Guleel) was located in the centre of the city, but by 2008 and 2009 the major peak neighbourhood was in the east of the city in Al Jameah. That is, new major peak neighbourhoods in Jeddah City tended to vary in terms of their location each year. The reason for the spatial spread of dengue fever cases after a major peak week is because the peak neighbourhood influences the neighbourhoods around it. The disease may be spread by *Ae. aegypti*, the main vector of dengue fever, but because its flight range is only 30 to 50 meters, its potential to spread dengue fever a great distance from hotspots is limited (WHO, 2011). More likely it is spread by people who travel to the peak neighbourhood for work or shopping, and after being infected spread the disease to other neighbourhoods. Another reason found is that both peak neighbourhoods for 2006 and

2007 to 2009 have very similar characteristics including a low socioeconomic status, high population density and a higher percentage of non-Saudi people than other neighbourhoods. High population density, for example, is an influential factor in the spread of dengue because people who are already infected, when bitten by *Ae. aegypti*, provide opportunities for the mosquito to transmit the disease to other people who live or work close to them. Yearly millions of people come through Jeddah City airport as pilgrims on their way to Makkah City. Many come from dengue fever regions and therefore may bring dengue fever or the *Ae. aegypti* with them. Jeddah City has a large number of non-Saudi people who are living and working there and many of these originally come from dengue affected countries. The neighbourhoods with low socioeconomic status can also influence dengue fever in different ways because such neighbourhoods often have bad environmental conditions, such as inadequate housing, untreated sewage, and surface water, all of which provide favourable breeding habitats for *Ae. aegypti*. Such neighbourhoods are also preferred locations for non-Saudi people to live because of lower housing costs.

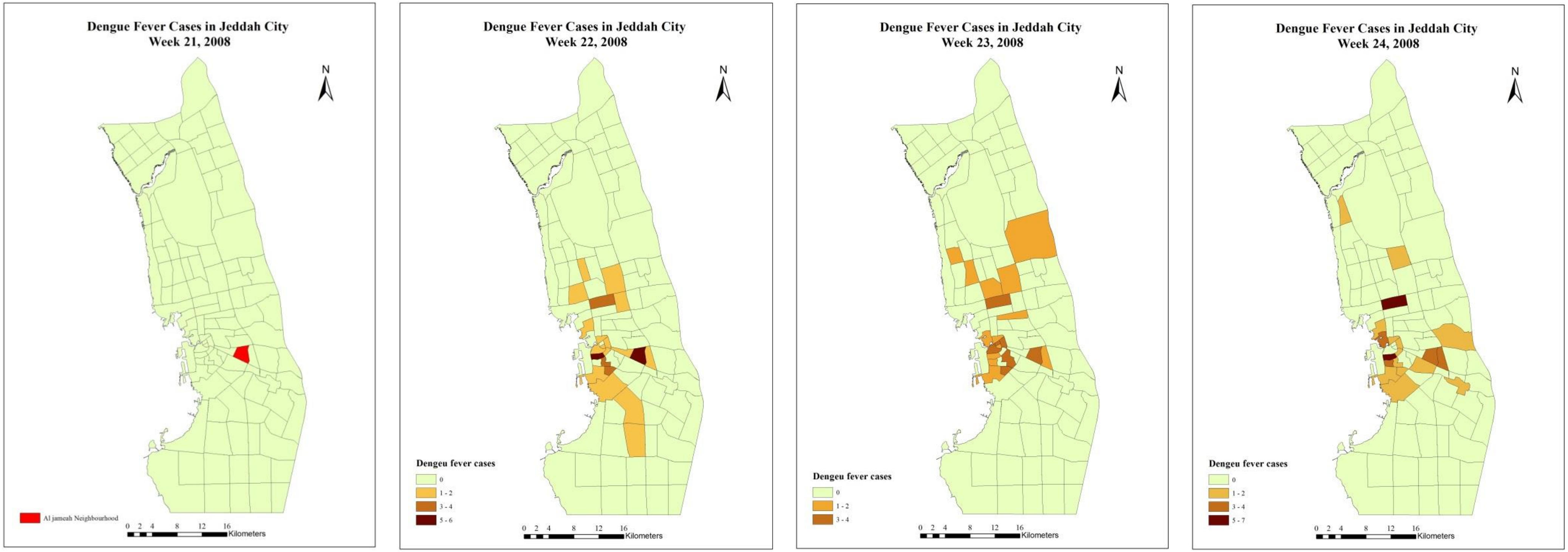

Figure 5.9 Dengue fever lag time weeks in Jeddah City (Weeks 21-24, Summer season), 2008

Sources: (Jeddah Municipality, 2012; Ministry of Health, 2010)

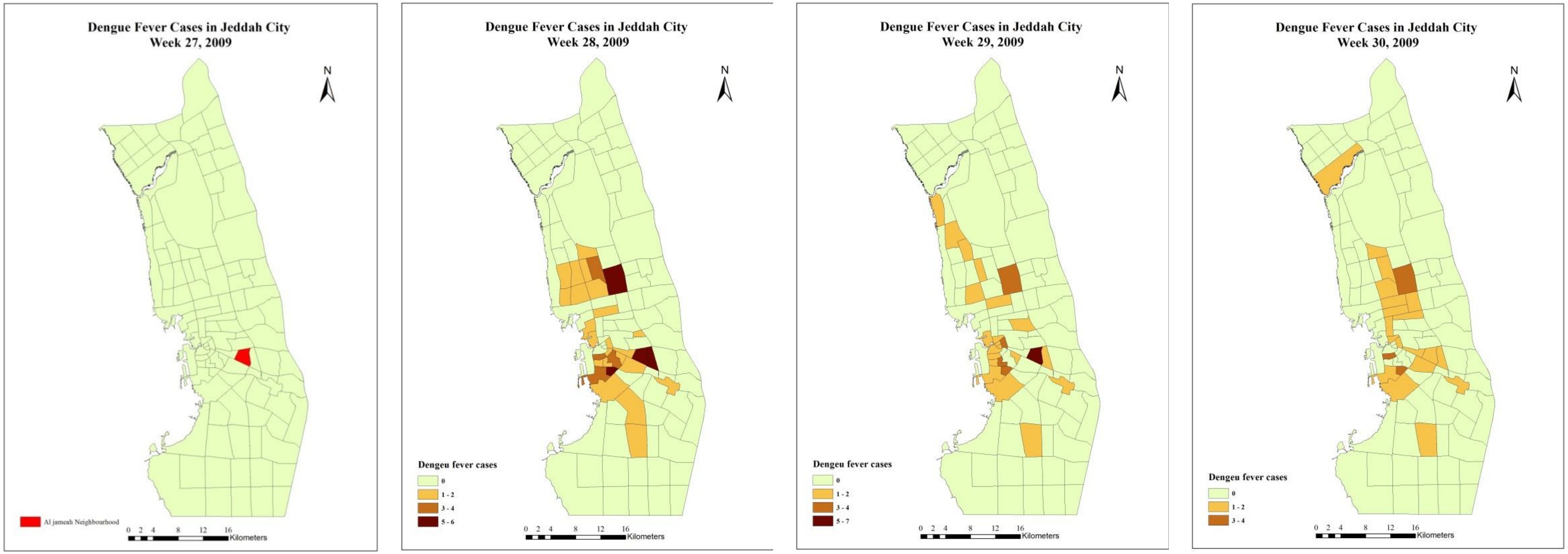

Figure 5.10 Dengue fever lag time weeks in Jeddah City (Weeks 27-30, Summer season), 2009

Sources: (Jeddah Municipality, 2012; Ministry of Health, 2010)

5.4 Explaining neighbourhood variations in the incidence of dengue fever

As outlined in Chapter 2 there have been few studies of neighbourhood variations in the incidence of dengue fever in Jeddah City. In light of the conceptual model discussed earlier, this section uses a number of different analyses to explore the key factors which may underlie such variations and their relationship to different pathways between neighbourhood characteristics and the distribution of dengue. It is posited that the distribution of dengue fever reflects key attributes of the physical and social environment and that these characteristics, both singly and in combination, affect dengue fever cases in Jeddah City in different ways. To consider these different relationships, three questions are posed:

1. What neighbourhood physical and social characteristics are the most important explanations of dengue fever cases? And to what extent is their impact consistent through time?

2. What are the key pathways between neighbourhood socioeconomic status and the incidence of dengue fever cases?

3. To what extent has the presence of surface water affected the incidence of dengue fever cases?

The following sections address each question in turn.

5.4.1 Effects of neighbourhood characteristics on dengue fever case rates

In this section bivariate correlations are used to explore the relationship between dengue fever rates and the physical and social characteristics of Jeddah City neighbourhoods. As indicated in Chapter 4, the dependent variables measure the number of dengue fever cases per 10,000 people over four years covering the period, 2006 to 2009. The independent variables consisted of five neighbourhood social characteristics; population density, 2009 (PopD09), percentage of non-Saudi people, 2004 (NS), sex ratio non-Saudi males per 100 females, 2004 (MFNS), sex ratio Saudi males per 100 females, 2004 (MFS) and one indicator of neighbourhood socioeconomic status, the percentage of respondents who ranked the neighbourhood as one of low socioeconomic status in 2013 (LSES). Physical characteristics included two measurements related to the area covered by surface water in each neighbourhood in each year from 2007 to 2009; the surface water percentage for the land area covered in the neighbourhoods (water7, water8 and water9) as well as the additional measures for the presence of surface water in areas surrounding the neighbourhoods within a two kilometre radius (water2K07, water2K08 and water2K09).

Table 5.4 shows the relationships between dengue fever case rates and the explanatory variables in Jeddah City neighbourhoods from 2006 to 2009. In 2006, the socioeconomic neighbourhood was the only variable significantly correlated to the dengue fever case rate in that year. This was not the case in 2007 when a wide set of correlations occurred between the case rate and neighbourhood variables, including the Saudi and non-Saudi sex ratio and percentage of non-Saudi people. Much the same pattern occurred in 2008, but in this year both neighbourhood population density and socioeconomic status were also significant. In 2009, the pattern was again different with only the Saudi and non-Saudi sex ratios being significant. The presence of surface water was not significant in any of the years.

The correlations show that neighbourhood socioeconomic status is the only variable that appeared on its own, as in 2006. In 2008, socioeconomic status appeared with other variables which suggest that socioeconomic status can act on its own or in combination with other factors. Moreover, the two significant variables in the years from 2007 to 2009, which did not change, are the Saudi and non-Saudi sex ratios. Both had a strong continuous effect on the rate of dengue fever cases.

Table 5.4 Relationship between dengue fever case rate and the explanatory variables in Jeddah City neighbourhoods, 2006-2009

Explanatory Variables	**Rate Cases, 2006**		**Rate Cases, 2007**		**Rate Cases, 2008**		**Rate Cases, 2009**		**Rate Cases, 2006-2009**	
	Cor*	***p*<**	**Cor**	***p*<**	**Cor**	***p*<**	**Cor**	***p*<**	**Cor**	***p*<**
PopD09	0.12	0.37	0.02	0.89	0.31	**0.02**	-0.12	0.37	0.07	0.58
MFS	-0.09	0.52	0.93	**0.00**	0.64	**0.00**	0.68	**0.00**	0.58	**0.00**
MFNS	-0.08	0.54	0.93	**0.00**	0.63	**0.00**	0.68	**0.00**	0.58	**0.00**
NS	0.09	0.50	0.36	**0.00**	0.53	**0.00**	0.23	0.08	0.34	**0.01**
LSES	0.30	**0.02**	0.15	0.28	0.48	**0.00**	0.19	0.17	0.36	**0.00**
water7	-	-	0.08	0.53	-	-	-	-	-	-
water8	-	-	-	-	0.06	0.65	-	-	-	-
water9	-	-	-	-	-	-	0.09	0.50	-	-
water2K07	-	-	0.08	0.55	-	-	-	-	-	-
water2K08	-	-	-	-	0.14	0.30	-	-	-	-
water2K09	-	-	-	-	-	-	0.16	0.24	-	-

* Pearson correlation

Multiple regression models for dengue fever case rates

Multiple regression was used to examine the relationship between the dengue fever case rate and social and physical neighbourhood attributes in Jeddah City neighbourhoods. The modelling was done in three stages. First, variables relating to population composition of neighbourhoods (MFS, MFNS and NS) were entered into the model. Second, models containing both neighbourhood compositional and structural characteristics, including neighbourhood socioeconomic status and population density were run. Finally, physical attributes of neighbourhoods, as indicated by the presence of surface water, were included in the models.

Table 5.5 and Table 5.6 shows stepwise multiple regression models for dengue fever case rates in Jeddah City neighbourhoods from 2006 to 2009. Table 5.5 indicates that the Saudi sex ratio showed a significant relationship to the dengue fever case rate in all years and indicates that Saudi males were more affected by dengue than Saudi females. By contrast the non-Saudi sex ratio was not significant once the Saudi sex ratio (MFS) entered into the model because MFS and MFSN were highly correlated (r=0.99, .p<0.00).

The second model in Table 5.6 reveals the effects of including the percentage of low socioeconomic status and population density. While the Saudi sex ratio remained the dominant predictor of dengue fever cases rates in three of the four years, neighbourhood socioeconomic status was still important in 2006, 2008 and for all years (2006-2009). Population density had an independent effect in 2007 while the population of non-Saudi was significant only in 2008 once socioeconomic status was accounted for.

Further multiple regression models were run, including the two surface water factors along with neighbourhood population and socioeconomic status characteristics. The results of this modelling were similar to the second model without the surface water data. This suggests that there is not a significant relationship between dengue fever cases and the presence of surface water.

Table 5.5 Multiple regression using population explanatory variables, 2006-2009

Explanatory variables	Step Entered at	Predictor Variables	Adjusted R Square	Beta Coefficient	*p*-value
Rate Cases, 2006	-	-	-	-	-
Rate Cases, 2007	1	MFS	0.86	0.93	0.00
	2	MFS and NS	0.88	0.90/0.12	0.00
Rate Cases, 2008	1	MFS	0.39	0.64	0.00
	2	MFS and NS	0.53	0.54/0.39	0.00
Rate Cases, 2009	1	MFS	0.45	0.68	0.00
Rate Ave Cases, 2006-2009	1	MFS	0.33	0.58	0.00

Table 5.6 Multiple regression using population and socioeconomic levels explanatory Variables, 2006-2009

Explanatory variables	Step Entered at	Predictor Variables	Adjusted R Square	Beta Coefficient	*p*-value
Rate Cases, 2006	1	LSES	0.07	0.30	0.00
Rate Cases, 2007	1	MFS	0.86	0.93	0.00
	2	MFS and PopD09	0.89	0.95/0.15	0.00
Rate Cases, 2008	1	MFS	0.39	0.64	0.00
	2	MFS and LSES	0.57	0.60/0.43	0.00
	3	MFS, LSES, NS	0.61	0.55/0.32/0.23	0.00
Rate Cases, 2009	1	MFS	0.45	0.68	0.00
Rate Ave Cases, 2006-2009	1	MFS	0.33	0.58	0.00
	2	MFS and LSES	0.42	0.56/0.32	0.00

It is important to understand the reason why the two Saudi and non-Saudi sex ratios explanatory variables were consistent through time from 2007 to 2009 (Table 5.4-Table 5.6). First, the number of non-Saudi males is much higher than females because in Saudi Arabia there are more male non-Saudi workers than females than in western countries because there are more men-only employment opportunities in Saudi Arabia. Most of the non-Saudi males come from infected countries like India, Indonesia and Bangladesh. Second, neighbourhoods with a high proportion of males, both Saudi tend to be found in the central parts of Jeddah City.

The high number of non-Saudi males and high density of Saudi and non-Saudi people in one area can be one of the main reasons for the spread of dengue fever. While the above findings suggest that gender differences are important factors in explaining neighbourhood variations in dengue they do not examine the extent to which dengue case rates interacted with other factors such as socioeconomic status. Table 5.7 shows that, for both Saudis and non-Saudis gender differences in dengue case rates were greatest in less affluent neighbourhoods because most of the poorer neighbourhoods have a high number of non-

Saudi males (either as a legal migrant worker or as an illegally hidden male). This difference was greatest for the non-Saudi population but nevertheless was still marked for the Saudi population with both groups also displaying a social gradient in both the number of cases and case rates.

Table 5.7 Number of dengue fever cases and case rates per 10,000 by gender in socioeconomic neighbourhood's status, 2006-2009

Neighbourhood SES		Saudi			Non-Saudi		
		Male	Female	Difference	Male	Female	Difference
High	Number of cases	45	24	21	32	8	24
	Rate cases per 10,000	5.8	3.2	2.6	4.9	2.2	2.6
Middle	Number of cases	175	100	75	212	36	176
	Rate cases per 10,000	7.4	4.5	2.9	9.9	2.7	7.0
Low	Number of cases	549	337	212	1002	238	764
	Rate cases per 10,000	18.3	12.3	6.0	18.8	8.1	10.7

5.4.2 Pathways between neighbourhood socioeconomic status and the dengue fever case rate

While neighbourhood sex ratios appear to be the most important factor influencing the distribution of dengue, it is evident that neighbourhood socioeconomic status also plays an important role, given that the bulk of dengue fever cases (74.5%) occurred in low socioeconomic status neighbourhoods. Neighbourhood low socioeconomic status also emerged as a significant predictor of dengue fever case rates in 2006 and 2008 and for the overall average rates between 2006 and 2009. As discussed in Chapter 2 three different pathways may underlie the links between neighbourhood socioeconomic status and dengue case rates. Such a link may be mediated by the effects of neighbourhood population densities, the presence of migrant groups, and neighbourhood lifestyle/local cultures. Given that low socioeconomic status neighbourhoods were often neighbourhoods with high population densities (r=0.59; p<0.00) and contained large non-Saudi migrant populations (r=0.50; p<0.00), many of whom are males and who have come from countries with a high rates of dengue fever, it was necessary to control for the influence of both these variables.

Table 5.8 indicates partial correlations between neighbourhood socioeconomic status and dengue fever rates after making controls, first for population density, and second for population density and the proportion of the population that was non-Saudi. In 2006, neither population density nor the proportion non-Saudi show any relationship with dengue fever case rates, so it is not surprising that controls for both variables did little to alter the significant relationship (r=0.30) between neighbourhood socioeconomic status and dengue fever case rates. In 2007, when there were very few cases, no relationship existed between low socioeconomic status and dengue fever case rates. Controls for population density (not significant) and non-Saudi (r=0.36; p<0.00) did not alter this situation.

In 2008 low socioeconomic status (r=0.48), population density (r=0.31) and non-Saudi (r=0.53) were all significantly related to the dengue fever case rate. Controls for population density reduced the correlation somewhat to 0.38 (p<0.00) and controls for both population density and non-Saudi to 0.25 (p<0.06), suggesting that both variables mediated the relationship between neighbourhood socioeconomic status and the dengue fever case rate, but not entirely.

In 2009 low socioeconomic status again showed no significant relationship with dengue fever case rates (r=0.19), but did so once controls were added for population density (partial r=0.32; p<0.02) and to some extent when both population density and non-Saudi were accounted for (partial r=0.24; p<0.08). A clearer situation is perhaps evident for the combined years 2006-2009 when low socioeconomic status (r=0.36) and non-Saudi (r=0.34), but not population density, were significantly related to dengue fever case rates. Controls for both population density and non-Saudi lowered, but did not eliminate the correlation (partial r= 0.31; p<0.02) between low socioeconomic status and dengue fever case rates, suggesting perhaps the existence of a third lifestyle pathway, linking low socioeconomic status and dengue fever cases (Table 5.8).

Taken together these results suggest that population density, and the presence of non-Saudis, may act in unison to affect dengue fever case rates. The effect of the presence of non-Saudis was more consistent than population density suggesting that high population density neighbourhoods are more likely to have higher dengue fever case rates when they are home to non-Saudi migrant populations. Controlling for both factors significantly reduced the link between low socioeconomic status and dengue fever case rates especially in 2008 and for the total period 2006-2009, but not in 2009 when controls lead to a much stronger relationship between low socioeconomic status and dengue fever case rates. The fact that the correlation remained significant lends some support for the neighbourhood lifestyles/local cultures model. As discussed in Chapter 2 dengue fever case rates may remain high when local populations, either because of fewer financial resources, lack of education, or different cultural values, become suspicious of, and resistant to, Government dengue fever control programmes. Resistance to public health initiatives has been common in other countries (Ávila Montes et al., 2004; Espinoza-Gómez et al., 2002; Fernandez et al., 1998; Kay et al., 2002; Lardeux et al., 2002; Leontsini et al., 1993; Nam et al., 2005; Raju, 2003; Sanchez et al., 2005; W Swaddiwudhipong et al., 1992; Wang et al., 2000) and so this could be an important explanation for neighbourhood variation in the incidence of dengue fever cases in Jeddah City.

Table 5.8 Partial correlations between dengue fever case rates and neighbourhood socioeconomic status controlling for different explanatory factors.

Variables	Control Variables	Partial Correlations	*p*-value
Rate Cases, 2006 and LSES	PopD09	0.28	**0.04**
	PopD09 and NS	0.28	**0.04**
Rate Cases, 2007 and LSES	PopD09	0.17	0.22
	PopD09 and NS	0.03	0.82
Rate Cases, 2008 and LSES	PopD09	0.38	**0.00**
	PopD09 and NS	0.25	0.06
Rate Cases, 2009 and LSES	PopD09	0.32	**0.02**
	PopD09 and NS	0.24	0.08
Rate Cases, Ave 2006-2009 and LSES	PopD09	0.40	**0.00**
	PopD09 and NS	0.31	**0.02**

5.4.3 Water problems and dengue fever in Jeddah City

The previous analysis indicated that the presence of surface water in a neighbourhood, or in surrounding neighbourhoods, was not a significant factor in explaining variations in rates of dengue fever in Jeddah City neighbourhoods. Nor did there appear to be any significant relationship between the presence of surface water and neighbourhood socioeconomic factors (Table 5.9 and Table 5.10). While there was some indication that poorer neighbourhoods were more exposed to surface water within the two kilometre buffer zone, the relatively large standard deviations indicate that considerable variation in exposure to the presence of surface water existed among Jeddah City neighbourhoods.

There are three reasons for the presence of surface water in Jeddah City. First, Jeddah City has had many issues dealing with water because of the shortage of water and not enough sources of water. As a consequence people in low status neighbourhoods tend to save their water in tanks and because most of the tanks are in a bad condition they frequently leak water. Second, the level of groundwater in Jeddah City is high because Jeddah City is located on the east coast of the Red Sea and groundwater can be seen everywhere in the city. Third, Jeddah City has a poor sewerage network and, because of this, sewage often leaks into the groundwater, which adds to an already existing problem. These environmental conditions are conducive to the survival and breeding of the *Aedes* mosquito (Jeddah Municipality, 2009b).

The main reason why no significant relationship existed between the presence of surface water and dengue fever case rates in Jeddah City is because Government Control Strategies for dengue fever have *successfully* controlled the surface water. A range of Control Strategies, each with different objectives, were used to dry and cover the surface water around Jeddah City, thereby stopping the influence of the surface water on dengue fever cases. One reason why these Strategies were successful could be due to the workers' diligence in their efforts to correct the situation. Because most of the surface water was visible, it could easily be monitored to observe any changes.

A significant amount of surface water was removed after the Jeddah Municipality drained it. No data are available for surface water conditions prior to 2006 because the Jeddah Municipality project to monitor and cover surface water began in 2007. Figure 5.11 to Figure 5.13 show the percentage of surface water in each neighbourhood from 2007 to 2009 and Appendix 6 shows the amount of surface water within the two and three kilometre buffer zones around the centre point of Jeddah City neighbourhoods from 2007-2009. It shows that Al Mahgar neighbourhood had the greatest amount of surface water in Jeddah City. As discussed previously this low socioeconomic status neighbourhood was one of the high hot spots of dengue fever in Jeddah City.

The percentage of land area covered in surface water has declined markedly since 2007 (Figure 5.11-Figure 5.13 and

Appendix 7). For example, the Guleel neighbourhood, a low socioeconomic status area and the major hot spot in 2006, at the time had the highest percentage of surface water in Jeddah City. In 2007 this was 2.06%, but by 2009 the proportion had decreased to 0.29%; however, while there was some indication that poorer neighbourhoods were more exposed to the hazards of surface water (but only within the two kilometre buffer area) in each year the standard deviations were highest for such neighbourhoods, indicating that significant variation in environmental conditions existed between them (Table 5.9). For this reason, and as in the case of dengue case rates, no significant correlations existed between neighbourhood socioeconomic status and surface water conditions (Table 5.10). The significant decrease in the presence of surface water in Jeddah City neighbourhoods supports the explanation as to why, by the time of this research, the surface water variables did not show any significant relationship to neighbourhood socioeconomic status or to dengue fever cases. In the next chapter the Control Strategies for dengue fever in Jeddah City are evaluated, and there is a discussion about surface water as one of the main projects.

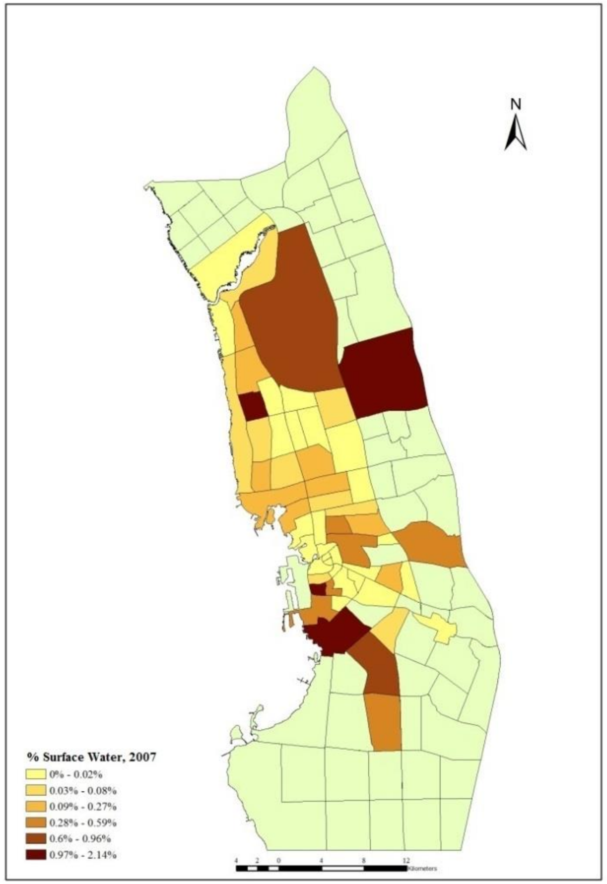

Figure 5.11 Percentage land covered by surface water in Jeddah City neighbourhoods, 2007

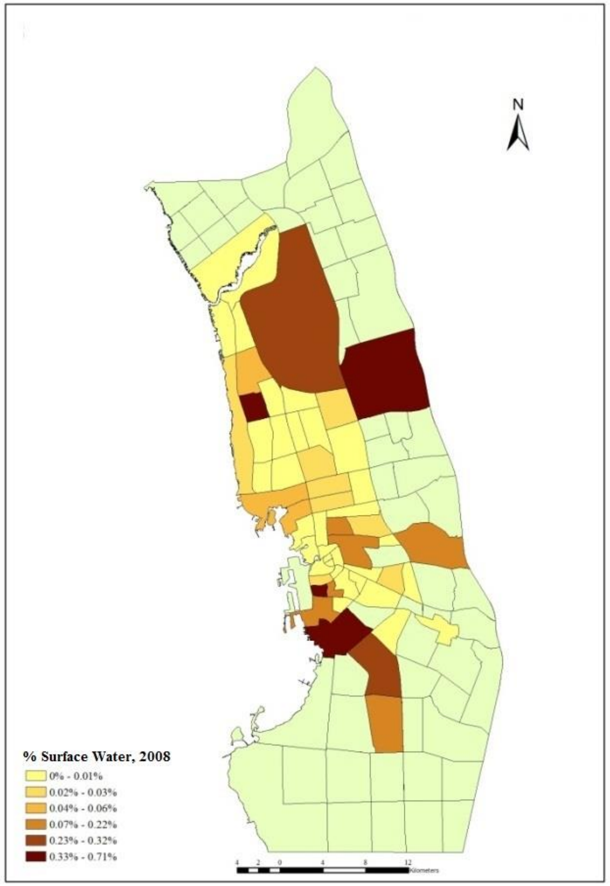

Figure 5.12 Percentage land covered by surface water in Jeddah City neighbourhoods, 2008

Sources: (Jeddah Municipality, 2012; Ministry of Health, 2010)

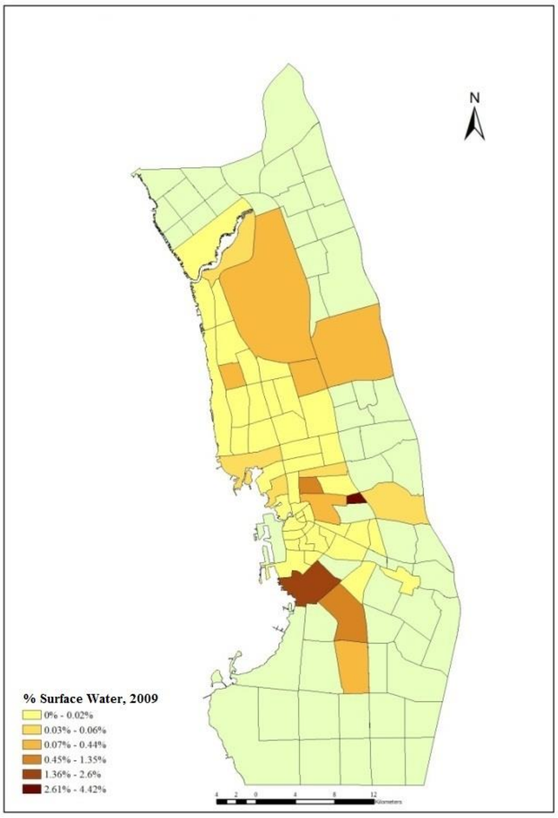

Figure 5.13 Percentage land covered by surface water in Jeddah City Neighbourhoods, 2009

Sources: (Jeddah Municipality, 2012)

Table 5.9 Percentage of neighbourhood land area covered in surface water and swamp area within two kilometres of neighbourhood centroids, by neighbourhood socioeconomic, Jeddah City 2007-2009

Surface water percentage								
SES	**Surface water, 2007**		**Surface water, 2008**		**Surface water, 2009**		**Surface water change, 2007-2009**	
	Mean	**STDEV***	**Mean**	**STDEV**	**Mean**	**STDEV**	**Mean**	**STDEV**
High	0.30%	0.66%	0.09%	0.23%	0.04%	0.10%	-0.26%	-0.57%
Mid	0.16%	0.24%	0.04%	0.08%	0.32%	1.01%	0.17%	0.77%
Low	0.31%	0.58%	0.10%	0.19%	0.15%	0.51%	-0.16%	-0.06%
Surface water in two kilometre buffer area size (km2)								
SES	**Surface water, 2007**		**Surface water, 2008**		**Surface water, 2009**		**Surface water change, 2007-2009**	
	Mean	**STDEV**	**Mean**	**STDEV**	**Mean**	**STDEV***	**Mean**	**STDEV**
High	8.43	12.21	6.35	12.67	3.60	6.00	-4.83	-6.21
Mid	11.67	14.36	7.55	11.45	9.30	16.54	-2.37	2.18
Low	14.09	18.15	12.09	18.91	24.30	94.74	10.21	76.58

Table 5.10 Relationship between surface water percentage and two kilometre buffer with neighbourhood socioeconomic status

Surface water percentage						
SES*	**Surface water, 2007**		**Surface water, 2008**		**Surface water, 2009**	
	Cor	*p*<	Cor	*p*<	Cor	*p*<
Low	0.02	0.87	0.05	0.70	-0.03	0.81
Surface water in two kilometre buffer area size (km2)						
SES	**Surface water, 2007**		**Surface water, 2008**		**Surface water, 2009**	
	Cor	*p*<	Cor	*p*<	Cor	*p*<
Low	0.16	0.29	0.23	0.09	0.18	0.19

5.5 The Influence of climatic conditions on dengue fever

Like many other cities in Saudi Arabia, Jeddah City has a warm climate. Summer temperatures are rather hot and often rise above 52˚C, while in winter the temperature is a more modest 25˚C (Presidency of Meteorology and Environment, 2011). There is very little rain in this region and only a small amount of it falls in winter (Kalid, Masroor, Jazem, & Z.I, 2008). From 2006 to 2009 there was a low amount of rain, with 70 mm the maximum rainfall, in the winter of 2009, during week 48 (Presidency of Meteorology and Environment, 2011). Because of its coastal location, Jeddah City has high humidity on most days of the year, but more especially in summer (Kalid et al., 2008). These conditions play a significant role on the population density of mosquitoes (Ministry of Health, 2010; Presidency of Meteorology and Environment, 2011). In this section, two questions are addressed:

1. To what extent do climatic variables influence the number of dengue fever cases?

2. To what extent do seasonal variations in dengue fever cases vary by neighbourhood social status?

5.5.1 Climate variations and dengue fever cases

To understand the influence of climatic factors on dengue fever this section explores the extent to which the incidence of dengue fever varies by season followed by a more explicit consideration of the effects of temperature and humidity on the number of dengue fever cases. According to Christophers, (1960), the temperature and humidity in summer may have a great influence on the survival and ration of mosquitoes. Adult mosquitoes cannot survive beyond the temperature of 40°C. Kalid et al., demonstrated that high temperatures shorten the viral development rate; however, such temperatures can also increase the number of infective mosquitoes (Kalid et al., 2008).

Seasonal variations

Figure 5.14 - Figure 5.17 show the number of dengue fever cases plotted weekly from 2006 to 2009. Across each of these years, the number of dengue fever cases typically increased around the summer season; however, considerable variation in the weekly number of cases varied annually. In 2006 more dengue cases were recorded between the spring and summer weeks and the highest number of cases was in week 16. In 2007, despite a peak in week 27, overall there were no clear seasonal variations because of the low number of dengue fever cases. In 2008 and 2009 higher numbers of dengue fever cases were clearly present in the summer season. The highest correlations between the weekly number of cases in each year were found between 2008 and 2009 (r=0.81) and 2006 and 2008 (r=0.69) while there was little correlation between 2007 and the other years.

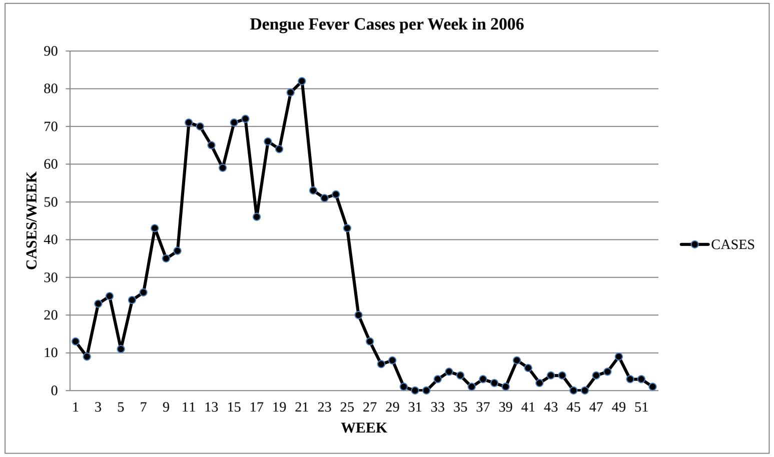

Figure 5.14 Dengue fever cases shown by week from 2006

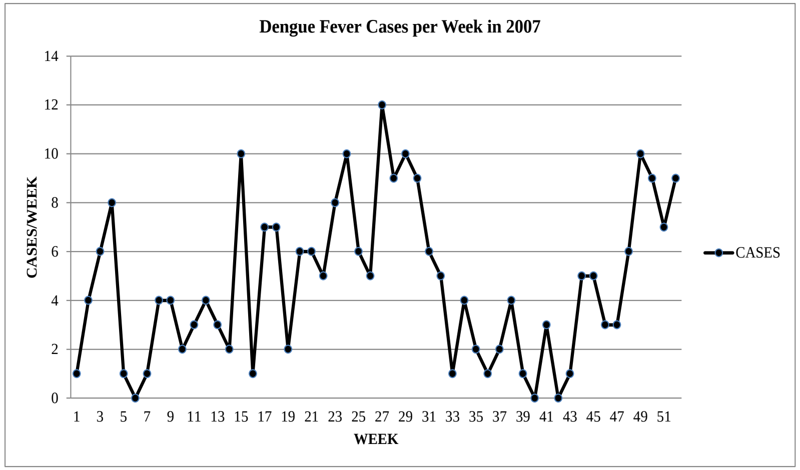

Figure 5.15 Dengue fever cases shown by week from 2007

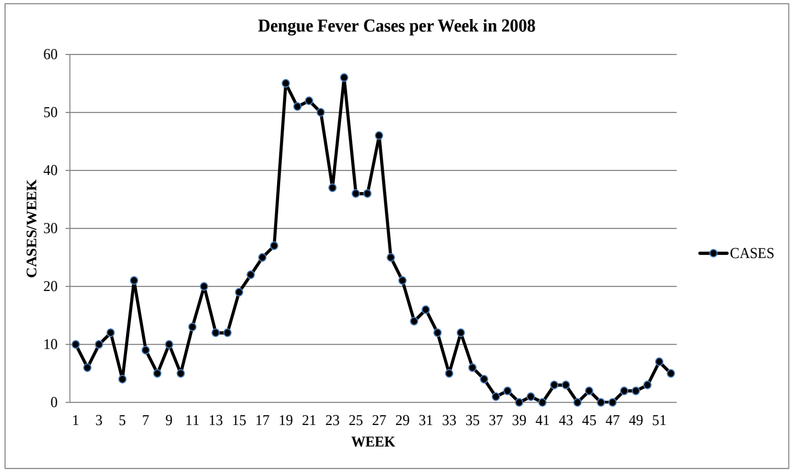

Figure 5.16 Dengue fever cases shown by week from 2008

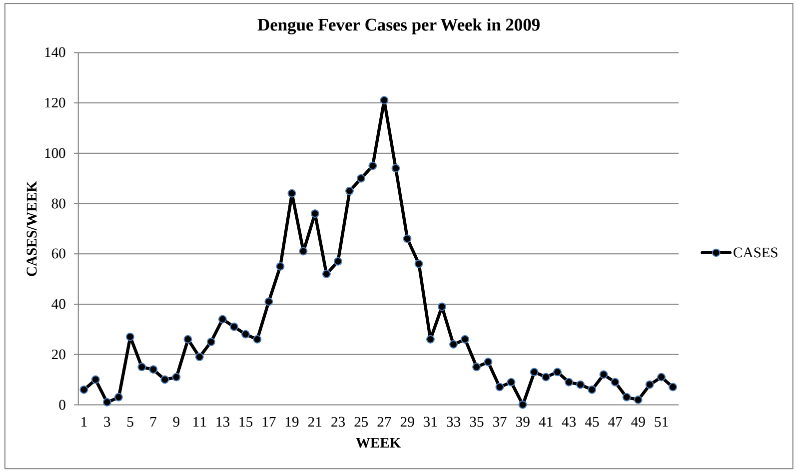

Figure 5.17 Dengue fever cases shown by week from 2009

Source: (Ministry of Health, 2010)

Variations in temperature and humidity can play a very important part in explaining rates of dengue fever in Jeddah City. To examine the influence of these factors cross tabulations were undertaken for the total number of dengue fever cases per week and the weekly climate variables. These comprised of the mean, maximum, and minimum temperatures as well as the same measurements for humidity (Appendix 10-Appendix 17). The number of dengue fever cases and all the climate variables were divided into quartile groups, ranging from 1 (*lowest*) to 4 (*highest*) as seen in (Appendix 18-Appendix 29). By analysing the data on all of these variables, the relationship between the number of dengue cases and the different climatic factors could be determined.

Temperature effect

The relationship during 2006 to 2009 between the weekly numbers of dengue fever cases and the weekly average of the maximum, mean and minimum temperature found that the highest number of dengue fever cases occurred in the hottest weeks with the lowest humidity. This can be seen in Table 5.11, for example, which shows that the odds of having more than 25 cases were six times greater when the average maximum weekly temperature exceeded 38.67^{o}C. The weekly average of the mean and minimum temperature relationship with the weekly numbers of dengue fever cases are in Appendix 30 and Appendix 31.

Figure 5.18 to Figure 5.20 show the relationship between the weekly number of dengue fever cases and the weekly average of the mean, maximum, and minimum temperature. The weekly average of maximum and minimum temperatures were not linear with the weekly number of dengue fever cases when the average maximum and minimum temperature increased or decreased, but Figure 5.18 shows the weekly average of mean temperature is significantly linear with the weekly number of dengue fever cases. This illustrates that the average of mean temperature had more effect on dengue fever in increasing the number of cases than the weekly average of maximum and minimum temperatures.

Humidity effect

The relationship between the weekly number of dengue fever cases (2006-2009) and the weekly average of maximum, mean, and minimum humidity shows that dengue fever cases are always highest when humidity is lowest. Table 5.12 shows that the odds ratio of having more than 25 cases was 92% less (0.08) when the averaged maximum weekly humidity was greater than 84.43%. The weekly averages of the mean and minimum temperature relationship with the weekly numbers of dengue fever cases are located in Appendix 32 and Appendix 33.

Figure 5.21 to Figure 5.23 shows the relationship between the weekly number of dengue fever cases and the weekly average of maximum, mean, and minimum humidity. It is evident that the weekly averages of maximum, mean and minimum humidity were significantly linear relationships when they were increasing or decreasing.

Thus, the analyses show distinct relationships between the number of dengue fever cases and the climate variables (temperature and humidity). Weekly averages of mean temperature had a linear relationship to dengue fever cases, but this was not true of average maximum and minimum temperature. In the case of humidity, relationships were linear regardless of which measure was used.

Table 5.11Cross tabulation for averaged maximum weekly temperature and weekly dengue cases 2006-2009

Averaged Maximum Weekly temperature	Dengue Fever Cases		Odds Ratio
	<2 cases	>25 cases	
<31.94	8	4	1
31.95-35.86	10	17	3.4
35.87-38.66	16	17	2.125
>38.67	6	18	6

Table 5.12 Cross tabulation for averaged maximum weekly humidity and weekly dengue cases 2006-2009

Averaged Maximum Weekly Humidity	Dengue Fever Cases		Odds Ratio
	<2 cases	>25 cases	
<75.42	5	21	1
75.43-79.56	5	18	0.86
79.57-84.42	12	11	0.22
>84.43	18	6	0.08

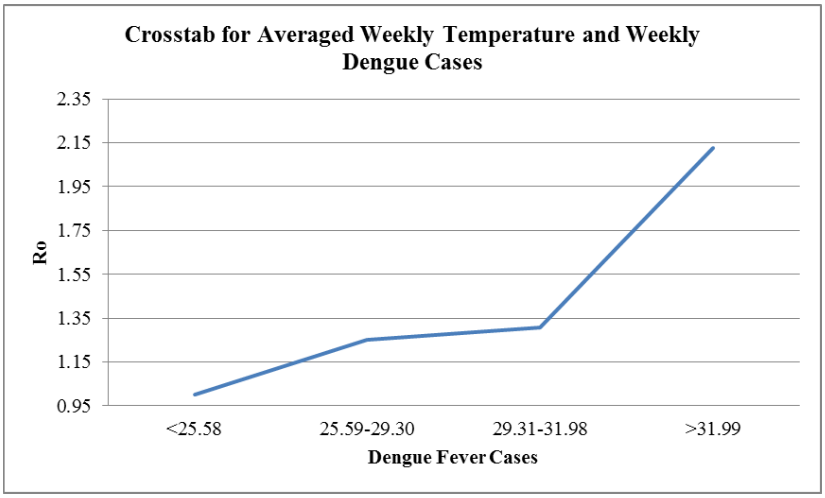

Figure 5.18 Cross tabulation for averaged weekly temperature and weekly and weekly dengue fever cases, 2006-2009

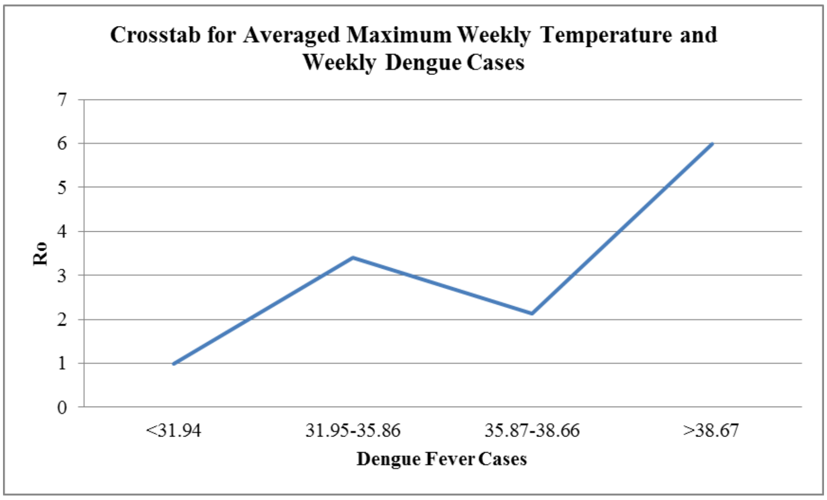

Figure 5.19 Cross tabulation for averaged maximum weekly temperature and weekly dengue cases, 2006-2009

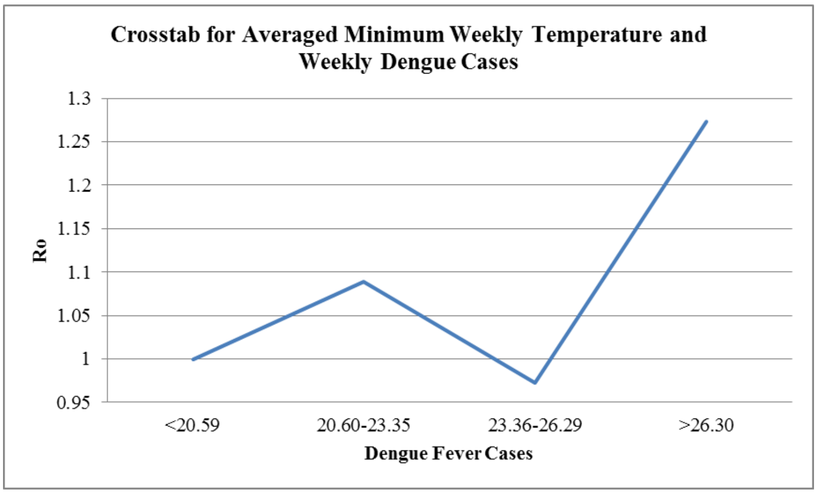

Figure 5.20 Cross tabulation for averaged minimum weekly temperature and weekly dengue fever Cases, 2006-2009

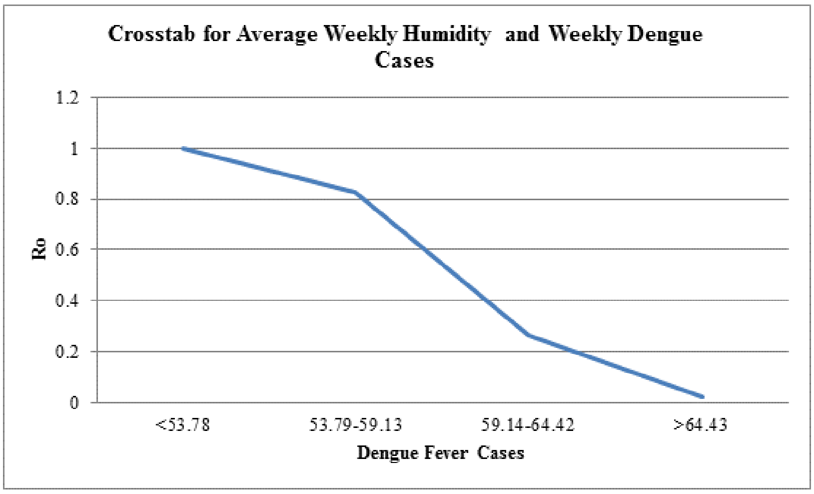

Figure 5.21 Cross tabulation for averaged weekly humidity and weekly dengue cases 2006-2009

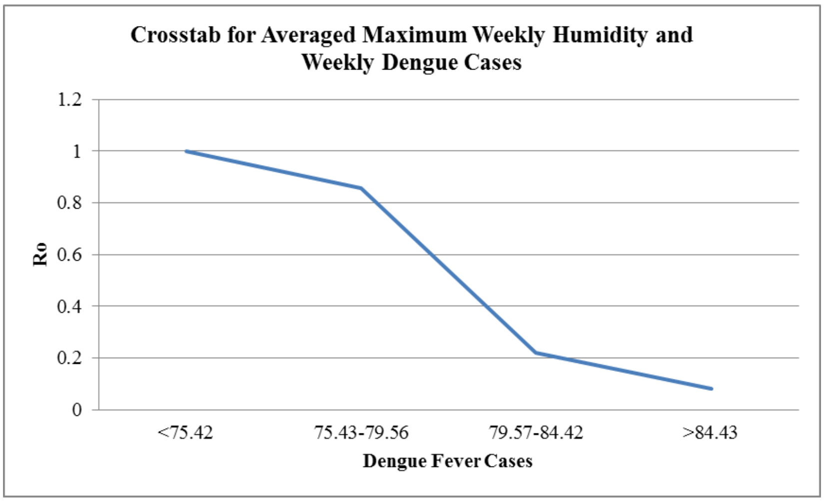

Figure 5.22 Cross tabulation for averaged maximum weekly humidity and weekly dengue cases, 2006-2009

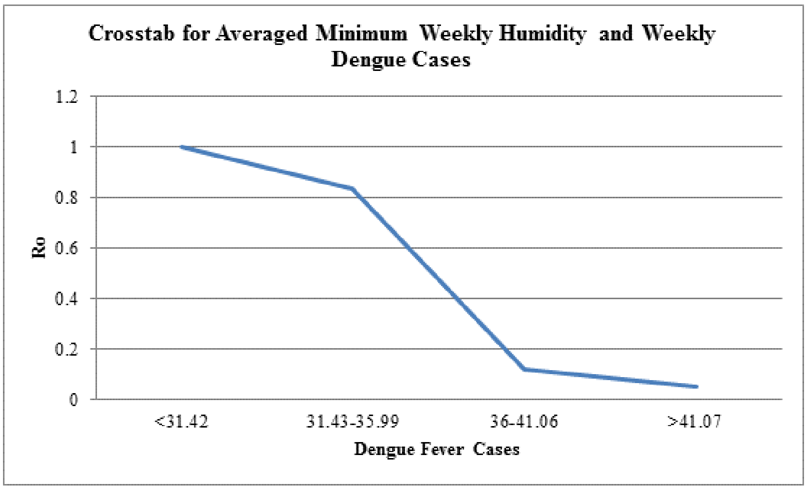

Figure 5.23 Cross tabulation for averaged minimum weekly humidity and weekly dengue cases 2006-2009

5.5.2 Effect of neighbourhood socioeconomic status in seasonal variations

Although climatic factors have an impact upon the incidence of dengue fever, this may vary depending upon the socioeconomic status of urban neighbourhoods. The aim of this section, therefore, is to explore the extent to which such variations occurred between 2006 and 2009. Figure 5.25 to Figure 5.27 indicate seasonal variations in the number of dengue fever cases in Jeddah City by neighbourhood socioeconomic status from 2007 to 2009. They show that while the number of dengue fever cases increased in all neighbourhoods during the summer season, this increase was greatest in low socioeconomic neighbourhoods.

While this trend was evident in all three years these were significant variations in the timing of the peak number of cases. In 2006 the highest numbers of dengue fever cases occurred between the spring and summer seasons (Figure 5.24). Furthermore, as can be seen in Table 5.13, the weekly relationship between dengue fever cases and mean temperatures and mean humidity was generally stronger in low and middle socioeconomic status neighbourhoods. The average weekly mean temperatures and mean humidity variables from 2006 to 2009 revealed that there was a relationship between them, and there were significant correlations for every year. In 2007 and 2008 the average weekly mean temperatures and mean humidity variables were not significant among dengue fever cases in high status neighbourhoods which indicates that the influence of dengue fever did not spread and reach these neighbourhoods.

Table 5.13 shows the relationship between neighbourhood socioeconomic status neighbourhoods with seasonal factors, mean temperatures and mean humidity variables which can be due to the environmental conditions and human behaviour at the hottest time of the year. People typically become more active during this time and unintentionally subject themselves to situations, which may influence the number of dengue fever cases. In the hot season people need more water and Jeddah City has a problem as there is a chronic shortage of water. People who reside in poor neighbourhoods are more likely to try to save their water, which leads to poor conditions. Because of this, the *Ae. aegypti* mosquitoes thrive and use these areas as breeding sites. Another factor is the housing conditions in the low socioeconomic status neighbourhoods. Houses in this time of year are kept cool. Because the *Ae. aegypti* mosquitoes die around 40^{o}C, they seek cooler areas such as the inside of people's homes. Houses in poorer areas do not offer as much protection against the *Ae. aegypti* mosquitoes because people who live there cannot afford air conditioners for each room. Normally the doors and windows are left open for fresh air and this in turn allows easy access for the *Ae. aegypti* mosquitoes to enter houses on the hottest days. Moreover, people do not have air conditioners in their bedrooms because they prefer to sleep on the roof of their houses in the cool air. This results in people exposing themselves to the dangers of dengue fever.

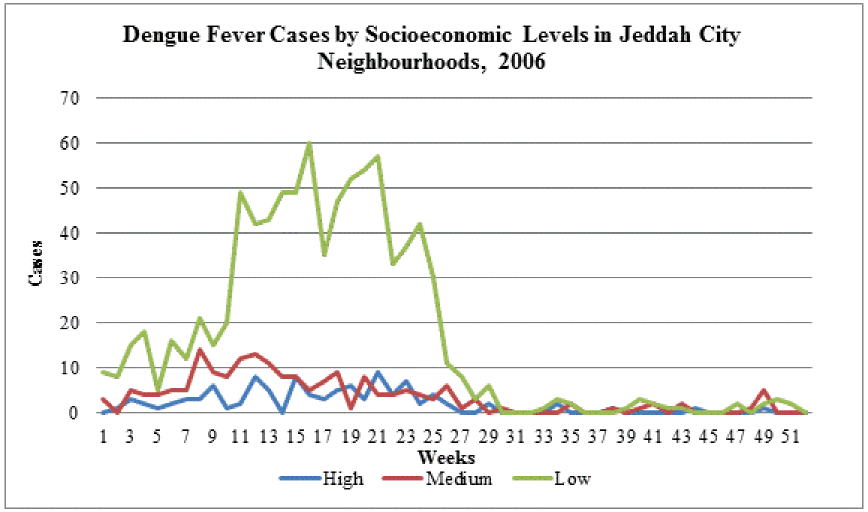

Figure 5.24 Dengue fever cases by socioeconomic levels in Jeddah neighbourhoods, 2006

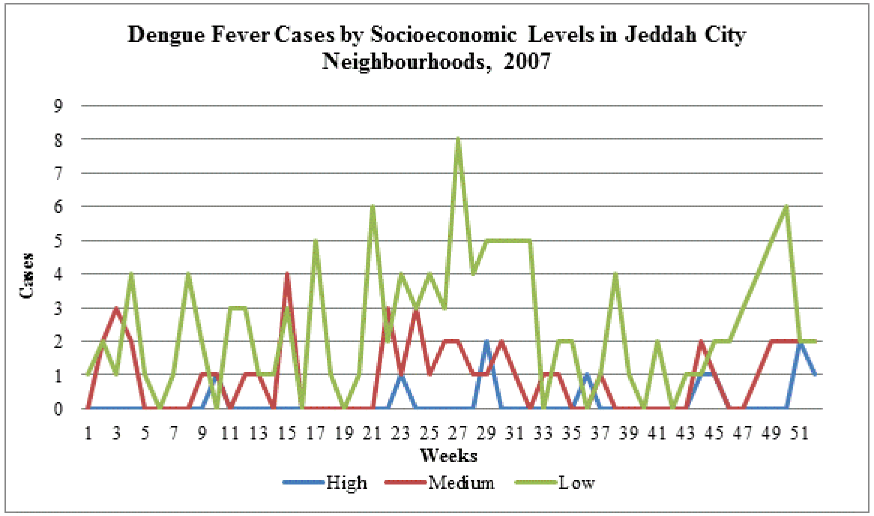

Figure 5.25 Dengue fever cases by socioeconomic levels in Jeddah neighbourhoods, 2007

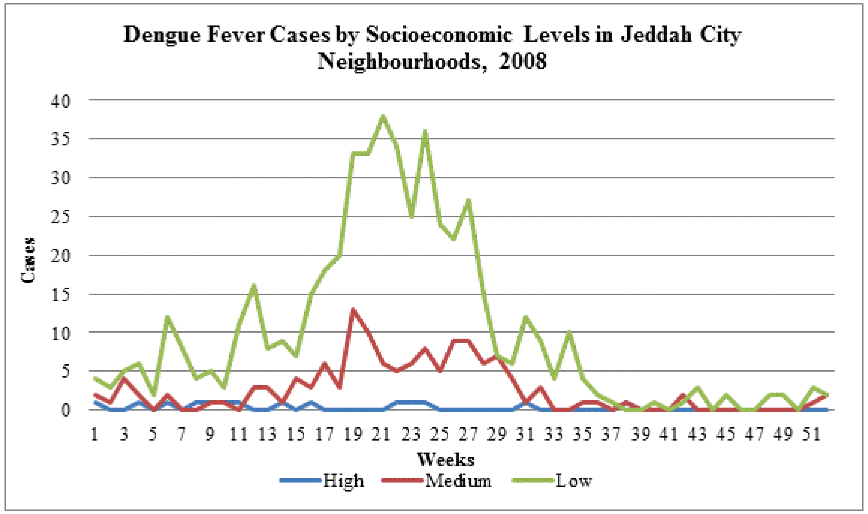

Figure 5.26 Dengue fever cases by socioeconomic levels in Jeddah neighbourhoods, 2008

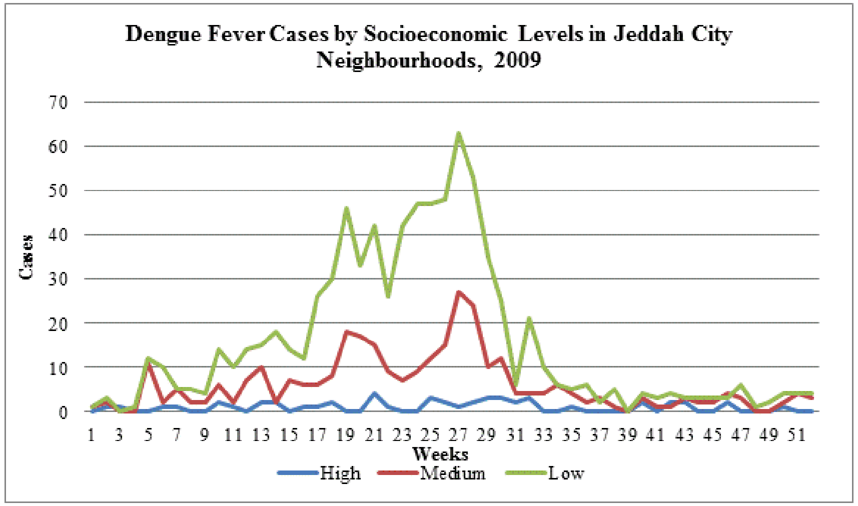

Figure 5.27 Dengue fever cases by socioeconomic levels in Jeddah neighbourhoods, 2009

Table 5.13 Weekly relationship between dengue fever cases in the socioeconomic status neighbourhoods and average week of the climate variables

Climate variables, 2006	**High SES**		**Middle SES**		**Low SES**	
	Cor	***p***<	**Cor**	***p***<	**Cor**	***p***<
Temperature mean	-0.02	0.90	-0.32	0.02	-0.06	0.66
Humidity mean	-0.27	**0.05**	-0.21	0.14	-0.27	**0.05**
Climate variables, 2007	**High SES**		**Middle SES**		**Low SES**	
	Cor	***p***<	**Cor**	***p***<	**Cor**	***p***<
Temperature mean	-0.00	0.97	-0.07	0.64	0.27	**0.05**
Humidity mean	-0.01	0.94	-0.27	**0.05**	-0.02	0.87
Climate variables, 2008	**High SES**		**Middle SES**		**Low SES**	
	Cor	***p***<	**Cor**	***p***<	**Cor**	***p***<
Temperature mean	-0.19	0.16	0.35	0.01	0.31	**0.02**
Humidity mean	0.15	0.27	-0.21	0.13	-0.16	0.26
Climate variables, 2009	**High SES**		**Middle SES**		**Low SES**	
	Cor	***p***<	**Cor**	***p***<	**Cor**	***p***<
Temperature mean	0.34	**0.01**	0.40	**0.00**	0.49	**0.00**
Humidity mean	-0.43	**0.00**	-0.41	**0.00**	-0.48	**0.00**

5.6 Summary

The aim of this chapter has been to explore the patterns and causes of dengue fever in Jeddah City. It began by focusing on the spatial and temporal trends of dengue fever in Jeddah and how these had changed over time. This preliminary overview was followed by more detailed analyses which sought to understand the importance of different physical and social environmental factors that are thought to be important in influencing the incidence of dengue at the neighbourhood level. The results found that the centre and south Jeddah City neighbourhoods had more dengue fever cases and those neighbourhoods had poorer living conditions, high population densities and greater numbers of immigrants. Spatial analysis of dengue fever cases using hot spot analysis revealed that the centre and south Jeddah City neighbourhoods contained above average concentrations of dengue fever cases. Spatio-temporal analysis also found a subsequent spread of dengue fever cases surrounding away from such hot spots following the major peak weeks in the summer season. Neighbourhood variations in dengue case rates reflect a number of inter-related factors. Stepwise multivariable linear regression was used to examine the importance of different physical and social predictors of dengue case rates and found the Saudi sex ratio was the most influential explanatory variable across the four years studied.

Neighbourhood socioeconomic status was also a significant predictor of dengue fever cases in 2006 and 2008 and for 2006 to 2009 but this factor also reflected other neighbourhood characteristics, and partial correlation was used to explore different possible pathways linking neighbourhood social characteristics to dengue rates. While the effects of higher population densities and the presence of migrant groups appeared to be significant intermediary variables so too was there some evidence of the importance of local cultural factors in influencing the incidence of dengue. On the other hand, neighbourhood physical characteristics, such as the presence of surface water in a neighbourhood were unrelated to dengue fever case rates in Jeddah City.

The analysis of the impact of climatic factors on dengue in Jeddah City found that more dengue cases showed up when the temperature was high and humidity was low but the effect of seasonal variation on dengue fever cases varied markedly according to neighbourhood socioeconomic status. The summer season peak in dengue fever cases was found to be mainly confined to low status neighbourhoods, not middle and high status neighbourhoods, where only minor seasonal variations were evident.

Chapter 6: The Control Strategies for Dengue Fever in Jeddah City

6.1 Introduction

There have been a number of studies from around the world evaluating the efforts to control dengue fever, based on the WHO's recommendations as applied by individual countries. These studies were reviewed in Chapter 2 (Section 2.6), and provide a better understanding of how dengue fever has been controlled in recent years. The Control Strategies for dengue fever used in Jeddah city were reported in Chapter 3 (section 3.6), but until now there have been no studies conducted on how well Jeddah City's dengue Control Strategies have been implemented.

This chapter presents the analysis of data collected from interviews undertaken with key informants involved in dengue fever control in Jeddah City. As noted in Chapter 4 (Section 4.3.2) this part of the project does not constitute a systematic evaluation of the policy and strategies. Instead, it concentrates on the process of implementing the operational Strategies in Jeddah City. This chapter reports on interviews with 15 people who were working, or had worked recently, on dengue fever projects in Jeddah. They included interviewees from Jeddah Municipality, the Ministry of Agriculture, and from the Ministry of Health, with the roles they held in their respective organisations, ranging from project leaders to field supervisors. The interviewees were purposefully selected to provide a variety of perspectives on the Control Strategies and their implementation. The interviews provide insights into how the Government Strategies work, how they have been implemented, and what changes might be needed in the future.

The interview data is reported in themes and sub-themes, some of which were based on questions asked in the interviews, while others emerged from the data through the analysis process described in Chapter 4.

Main themes and sub-themes (see Figure 6.1)

As set out in Figure 6.1, five main themes were developed.

Theme 1: Workforce characteristics and capability. This theme is important in providing some understanding of the potential for providing effective, high quality interventions based on a skilled workforce.

Theme 2: Knowledge about dengue fever in Saudi Arabia and Jeddah City. This sets out the general understanding of dengue fever in Saudi Arabia and Jeddah City, but also reports on two key dimensions of knowledge: the pattern of dengue fever and the persistence of dengue fever in Jeddah City. This theme gives some indication of need for education about dengue as part of control interventions.

Theme 3: Operational Strategies for dengue fever control in Jeddah City. This theme focuses on the responsibilities of the operational agencies: the Ministry of Health, Jeddah Municipality, and Ministry of Agriculture, and how they carry out their tasks.

Theme 4: The progress of implementation is set out into four sub-themes which include: the relationship between the Ministry of Health, Jeddah Municipality, and Ministry of Agriculture in dengue fever control projects; job workers' duties and freedom in taking actions in the Strategies; community and worker awareness of dengue fever; and funding and resources. In this theme, the progress of implementation is reported, with each sub-theme presenting examples of how the Control Strategies for dengue fever are working in Jeddah City.

Theme 5: Overall view of Government Strategies in Jeddah City. This final theme reports on an overall assessment by the interviewees of progress in the implementation of Control Strategies for dengue fever in Jeddah City.

Each theme and sub-theme is discussed separately in sections 6.2-6.6, below, and summarised in section 6.7.

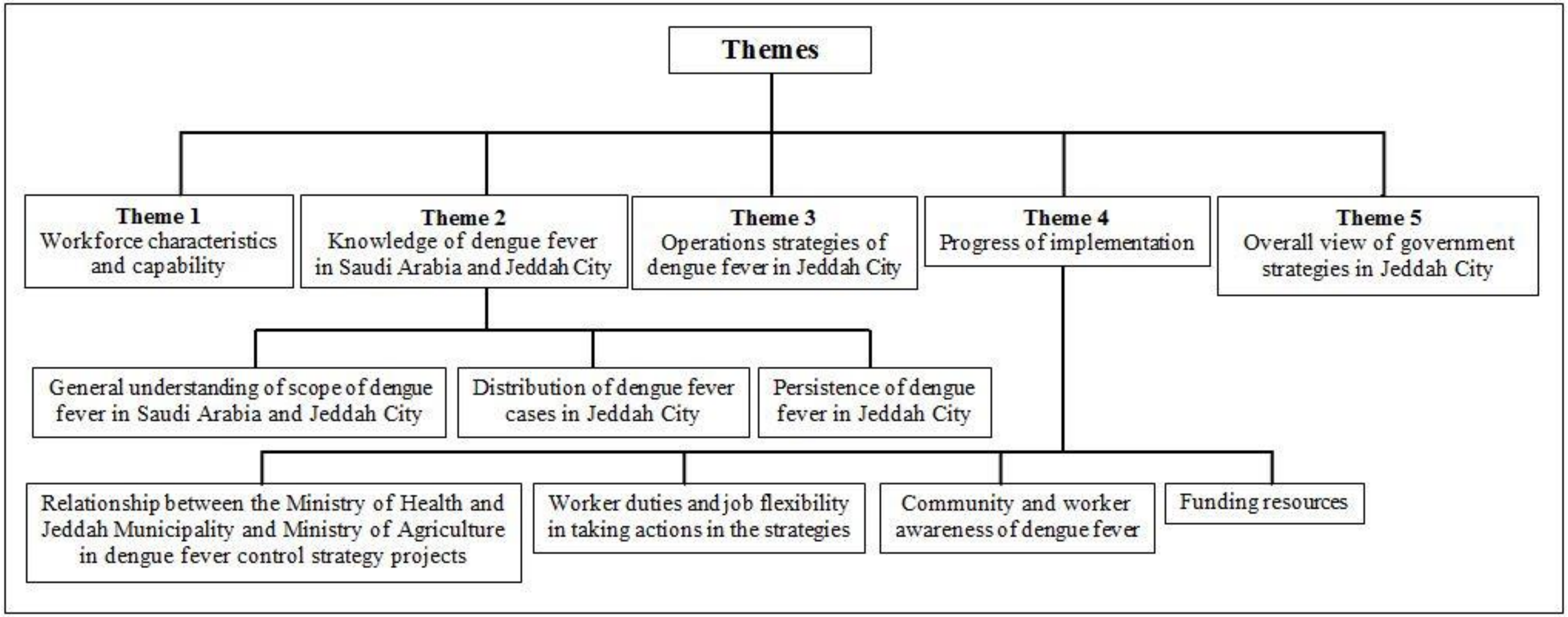

Figure 6.1 Dengue fever interview themes analysis

6.2 Workforce characteristics and capability

Dengue fever control is a specialised area of public health work requiring suitable training and aptitude. This first theme reports on how interviewees saw their own and others' suitability for their jobs in dengue control. The 15 interviewees represented a variety of roles and responsibilities, but only seven considered themselves to have an appropriate background or education for their position. Interviewees from Jeddah City in particular reported themselves to be less well prepared for their work. Across the interviewees the type and level of qualifications varied; some of them had a high level of education (e.g. PhD in Engineering) whereas others had been trained specifically to work with dengue fever in their particular job.

Some of those interviewed who did have suitable qualifications were nevertheless no longer working on dengue fever projects in Jeddah City for a variety of reasons. In general, most of the interviewees were not satisfied with the way the personnel aspects of projects had been managed. They reported that there were too many people working on dengue fever projects who were not qualified for their job, or who needed more training.

Some of the interviewees who were working in senior positions reported that they, themselves, did not have enough relevant education, and some of them felt they did not have a good enough working knowledge of dengue fever. One person who was approached to be interviewed and was working on a dengue fever project acknowledged his lack of knowledge and said, "I know someone else that would be able to answer the questions better than I could." Another person commented, "All field workers who are working in the Municipality inside and outside the houses to control dengue fever are not good, and they do not know their job well" (Interviewee, 12).

One interviewee reported that a candidate had been appointed without even an interview because he knew someone who could help him to get the job, and eventually he became a supervisor with a relatively high salary (later reduced). Another interviewee mentioned that he had had a project leader with only an elementary school education, but that the person was not in the position for long because he created too many problems. There were also four out of the 15 people interviewed whose background and education were completely unrelated to the control of dengue fever. An interviewee reported that "most of the people working with dengue fever have very little knowledge about insects in general, especially the *Aedes* mosquito" (Interviewee, 12). One person with relevant qualifications, when asked about his position, was so uncertain about the exact job title that he had to look at some documents in order to confirm the title of his position.

Overall, it appears that the characteristics and capabilities of the workforce, as reported by the interviewees, are very variable and probably not adequate overall, and this may have implications for the quality of dengue control. To ensure quality of the Control Strategies for dengue fever in Jeddah City, the Government must have workers with levels of education and training that are related to dengue fever and the tasks they undertake.

6.3 Knowledge of dengue fever in Saudi Arabia and Jeddah City

a) General understanding of scope of dengue fever in Saudi Arabia and Jeddah.

All the interviewees stated correctly that Jeddah City has the biggest problem with dengue fever in Saudi Arabia, and that no city in Saudi Arabia came close to Jeddah City in terms of its dengue fever predicament. Senior staff fully understood the background to the problem. One reported that the first time dengue fever was found was in 1993, but by 1994 it had become an epidemic with 469 cases in that year, including two fatalities. Another interviewee said the first cases were discovered in the Soliman Fakeeh Hospital in Jeddah City in 1994. There was a consultant from the USA working in the hospital who also worked for WHO. This consultant reported the situation to the WHO and, after that, the Jeddah Municipality took steps to control dengue. The interviewee noted, "I believe without that report to the WHO, Jeddah City would not have had any strategies [or] controls" (Interviewee, 9). After that, dengue fever cases seemed to disappear, but in 2006 they returned.

Most of the interviewees reported that there were several other cities in Saudi Arabia which had reported dengue fever, including Makkah, Qunfudah, Ta`if, Al-Madinah, Najran, and Al-lith and Jazan. Approximately half of the interviewees specifically mentioned the city of Jazan and indicated that this city had a particular problem. One interviewee said "The *Ae. aegypti* mosquitoes in Jazan were found to be inactive by researchers in 1999" (Interviewee, 1) and another interviewee noted that "there are many cases in Jazan due to the water problems" (Interviewee, 12). Two interviewees alleged that Jazan in fact has a higher number of cases than Jeddah, but that the Government had not reported the statistics widely because that city does not have good health care, and it also has major environmental problems.

From the informants it can be concluded that dengue fever can be found in a number of cities in Saudi Arabia, but it is not always monitored by the Government as closely as it is in Jeddah City. One respondent commented that at some stage in the future Saudi Arabia may have an increasing number of cases across the country unless the Government takes the type of serious action to control it as occurs in Jeddah City.

b) Distribution of dengue fever in Jeddah City.

Those interviewees who were involved in dengue fever within the Jeddah City limits all agreed that at the present time dengue fever can be found right across the city. They reported that originally it had been found only in the centre of the Jeddah City, then in the south, and later in the northern part of the city: "It had spread very quickly and had been very contagious. Dengue fever has occurred mostly in the centre (old Jeddah City) and the south of Jeddah City and the fewest of cases occurred in the north" (Interviewee, 1).

One interviewee identified three density categories when talking about dengue in the city:

> "There are three density categories of dengue fever in Jeddah: high, mid and low. The high numbers of cases are located in the central part of the city in Glal, Albald, Aljamh and Alsafa neighbourhoods which have a low socioeconomic level and high density of population; the mid cases can be found in Albawadi neighbourhood which is a little north of the city, and the low numbers are seen in north Jeddah neighbourhoods located north of the city's centre which have a high socioeconomic level and low density of population and new neighbourhoods" (Interviewee, 15).

In the last three years dengue fever has been less obvious in some areas, such as in north Jeddah City, with cases identified in the south and centre of the city. Most of the interviewees agreed that the location of dengue fever in Jeddah City has changed from year to year. They indicated that more cases have been reported recently in areas that were not previously affected.

The interviewees were worried about the distribution of dengue fever spreading more and more each year, and reported that this can be seen as not only as a warning for Jeddah City but also as a warning for other cities close to Jeddah, such as Makkah and Al-Madinah.

c) Persistence of dengue fever in Jeddah City.

Many reasons have been suggested for the persistence of dengue fever in Jeddah City. The reasons given by the interviewees were connected to the shortage of water in the city and the need for households to store it, migration of non-Saudi people to Jeddah City, seasonal climate variation, environmental problems, cultural factors, and rapid urbanisation. One interviewee summarised some of these ideas:

> "Dengue fever in Jeddah City has become a problem these days and most people working in projects share the same ideas about the reason for dengue fever in Jeddah City. They say it is mainly due to non-Saudi people moving into the area, a hospitable environment for the *Ae. aegypti* mosquitoes, low education and the fact that many people do not think it's a serious problem" (Interviewee, 2).

The main reasons for the persistence of dengue fever, as identified by interviewees, are set out below:

Shortage of water and water storage

Four interviewees reported that Jeddah Municipality personnel understood that people who lived in poor areas of Jeddah City experienced water shortages. They stored their water in uncovered tanks or containers which were in a poor condition, and most of the tanks were leaking. The tanks/containers provided an environment hospitable to mosquitoes. To deter mosquitoes, the Jeddah Municipality gave the residents new tanks but many people secretly kept their old tanks in order to give themselves more water storage capacity. Later, when the Government discovered this, it discontinued the project of providing new storage tanks. A dengue control project to put screens on the top of tanks to deter mosquitoes was also unsuccessful because of chemical contamination of the water from the mesh on the screens. The difficulty of managing the water-shortage situation is illustrated by the following quotes:

> "The Jeddah Municipality was worried about the old tank condition because most of them were in very bad condition, and it's easy for the *Ae. aegypti* mosquitoes to go inside the tank and lay their eggs. In this case, it is going to be hard to control the mosquitoes in that area" (Interviewee, 3).

> "There was a project that used screens to cover the top of the tanks. The Jeddah Municipality had a big failure because the water volatility in hot weather and steam reached the screen and took some chemicals and mixed them with water. That project did not last for a long time, and they stopped it" (Interviewee, 3).

> "Wherever there is a shortage of water in Jeddah City, we can see more dengue fever cases and the Jeddah Municipality has to take action to find the right way to provide enough water for everyone living in Jeddah City" (Interviewee, 10).

Jeddah Municipality has not been able to resolve this problem because the water supply network is in poor condition almost everywhere in the city and it had not been practical to give tanks to all people to store their water.

Migration

Several interviewees reported that another reason for the appearance and persistence of dengue fever was the large number of pilgrims in Jeddah City. The pilgrims come from all parts of the world. Some of them may have dengue fever, may be non-symptomatic and are therefore probably unaware that they have the condition. The pilgrims enter the country through Jeddah City because Makkah City, their ultimate destination, does not have an international airport. The interviewees mentioned that most of the pilgrims come for only a short time, but there are many migrant people who have also come to Jeddah to work and remain there for extended periods. A large majority of these migrants are in Jeddah City illegally. They are the ones who tend to cluster in the central part of the city living in poor environmental conditions.

Some of the interviewees said that the first case found in Jeddah City was a person from Yemen which indicated that dengue fever had come from outside Saudi Arabia. One of the interviewees reported:

> “Many people from Yemen are living in old Jeddah City (centre city) and the number of cases is high in that area. Most of the fatal cases come from Yemen and the first two fatal cases as well. We had to test the people who were living with the first two cases and found that many of them had had dengue fever already and they did not know they had it until we told them” (Interviewee, 15).

Other interviewees claimed that people from East Asia in particular are also responsible for bringing dengue fever into Jeddah City. One interviewee said:

> “With most of the cases of dengue fever around the world in East Asia and every year, we have many people who come from countries in East Asia and we are not sure if they have dengue fever or not. Even if they have it, they do not show any symptoms because most of the dengue fever cases are in the first stage of the illness which may mean that they were infected a day or two before visiting Jeddah City and there is always the *Aedes* mosquito factor we have in Jeddah City” (Interviewee, 5).

Seasonal climate variation

Some interviewees claim that one of the most important reasons for dengue fever in Jeddah City is seasonal climate variation. As explained in Chapter 5, the variation in Jeddah’s climate has been a significant factor for the increase or decrease in the number of dengue fever cases.

Interviewees were aware of these variations and noted that the high humidity and temperature in general in Jeddah City provides good conditions for the *Ae. aegypti* mosquito. Several interviewees reported that in summer it might be expected that there would be more cases of dengue fever because, although the *Ae. aegypti* mosquitoes cannot survive for long periods outside in hot weather when the temperature is often over 40^{o}C, mosquitoes often go inside houses and live among the residents, increasing the residents’ chances of being infected with dengue fever. Interviewees noted that *Ae. aegypti* mosquitoes can be found in houses behind the curtains, in other cool places and around any fresh water. One interviewee noted that: “A study showed that the *Ae. aegypti* mosquitoes would die after the temperature reaches 45 degrees and the ideal temperature condition for the *Ae. aegypti* mosquitoes is between 26 and 33 degrees Celsius” (Interviewee, 2). The same interviewee suggested that people at home in the summer are at greater risk of dengue: “The Government had done a study and found more cases among women and children due to them being in the home more than men”.

Environmental problems

Most of the interviewees recognised that areas of standing water are important in maintaining populations of *Ae. aegypti* mosquitoes, and they noted the presence of two large lakes in Jeddah City: Al Arbaeen and Al Mask. Al Arbaeen is in the centre of the city and located between the Red Sea and the sewerage network. Al Mask Lake is in the east of Jeddah City and at one time was used for sewage disposal. Both lakes have created significant environmental problems in the past and were reported as hosting mosquitoes. Although most interviewees mentioned the two large lakes as attracting mosquitoes, few of the interviewees mentioned the large numbers of small areas of standing water across Jeddah City that were described in Chapter 5.

The City has undertaken remedial works to reduce the impact of these lakes on the environment as set out in the Jeddah City dengue fever Control Strategies. One interviewee said:

> “Jeddah Municipality decided to find a solution for that lake [Al Arbaeen] and started to use special fans that could be put inside the lake after they asked the right people about the lake situation. These fans can give the lake fresh air and keep the water moving. The result is the bad smell is almost gone and it has become clean with very few *Ae. aegypti* mosquitoes around” (Interviewee, 1). Figure 6.2 shows Al Arbaeen lake and the fans.

Two interviewees commented on why the eastern part of Jeddah City where the Al Mask Lake is located has had a high density of mosquitoes:

> “There is another big sewage lake (Al Mask) there. All the sewage trucks used to go there and empty the sewage into the lake; however, that lake has become dry now because three years ago the Government started draining it when they made two sewerage stations in north and south Jeddah City” (Interviewee, 12).

> “Al Mask Lake and other swamps used to be a big environmental problem in Jeddah City. That lake used to be a place of disease because *Ae. aegypti* mosquitoes used to be

found in large numbers around it, and it also had a bad smell of sewage which could be detected from far away. There were also crocodiles in that lake which is hard to imagine crocodiles living in Jeddah City because that is not the best environment for them" (Interviewee, 1).

Satellite images of the Al Mask Lake are shown in Figure 6.3. These suggest that the lake has become much smaller since 2007 and therefore likely to harbour fewer mosquitoes (Space Research Institute, 2010).

Figure 6.2 Al Arbaeen Lake

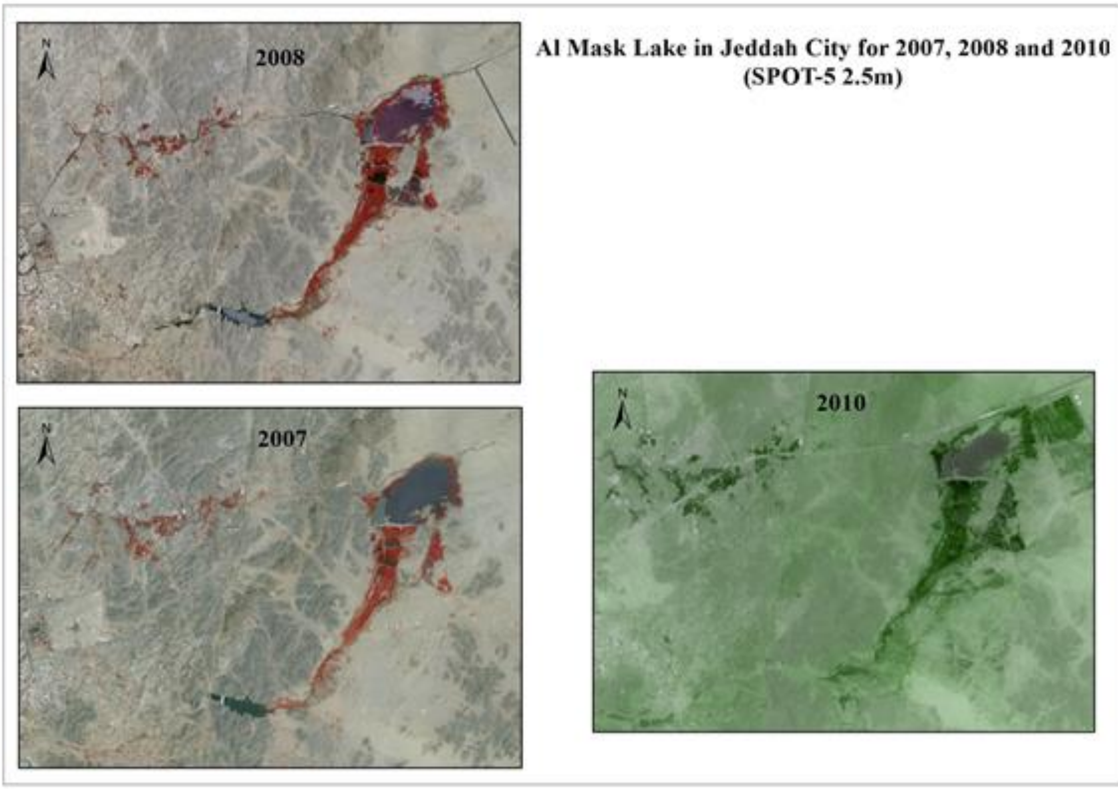

Figure 6.3 Al Mask Lake in Jeddah City for 2007, 2008 and 2010

Sources: (Space Research Institute, 2010)

Cultural factors

Culture also plays a role in the persistence of dengue fever. The consequences of this can be seen when the Government tried to control dengue fever in residential areas. Interviewees confirmed that when there was no man at home, the women living there would not permit Government officials to go inside their homes to look for and kill the *Ae. aegypti* mosquitoes. In addition, municipal dengue control officers were specifically forbidden by residents to enter bedrooms. An interviewee said:

> "It is really very hard to get inside the houses for spraying because of the privacy of the Saudi culture; it is almost impossible to go and spray the bedroom and other people would not open the door for us if there were no man in the house because women are not allowed to open the main door" (Interviewee, 5).

Moreover, in some cases when the person with dengue fever went to the hospital he/she did not give the correct personal information such as his/her phone number or the location of their house. This made it difficult to contact the cases later and locate the source of the dengue infection. As interviewee commented:

> "When people had got dengue fever, sometimes they refused to give personal contact information, especially women's information, because in the Saudi culture, some people do not talk to people who they do not know, especially a woman to a man. For that reason, we have got too many wrong phone numbers and even names" (Interviewee, 15).

Some interviewees explained how the Ministry of Health and the Jeddah Municipality work together to educate people by distributing brochures and informing people about dengue fever and the measures that need to be taken to prevent the mosquitoes. A number of interviewees indicated that the local people just do not understand this problem or take it seriously. One interviewee specifically reported that his recommendation was to educate people and the communities who were at risk from dengue fever.

Rapid urbanisation

While the number of dengue cases in North Jeddah is actually lower than in the centre of Jeddah City because of the lower population density, nevertheless a high number of *Ae. aegypti* mosquitoes are present in the northern part of the city. Some interviewees said that rapid urbanisation is a factor in the larger numbers of mosquitoes in north Jeddah City in particular. They reported that this is a fast growing part of the city with many new buildings erected recently and under construction but with little Government regulation.

> "Jeddah City is growing fast and around those buildings they have found a high density of *Ae. aegypti* mosquitoes. These new buildings require fresh water to mix the cement and other construction materials, and the *Ae. aegypti* mosquitoes are always around the fresh water" (Interviewee, 9).

It was reported that where traps have been set around these new buildings a high number of *Ae. aegypti* mosquitoes are found when the traps are checked. As one interviewee noted:

> "The main factor is that *Ae. aegypti* mosquitoes can be found in north Jeddah City because of the fresh water being used for the new buildings, and inside some of the basements of these new buildings the *Ae. aegypti* mosquitoes can be found more than

anywhere because the fresh water is there along with the high humidity" (Interviewee, 7).

The results reported above suggest that overall the interviewees were familiar with many of the reasons for the persistence of dengue fever in Jeddah City and had good insights into how local conditions needed to be changed. Most of the interviewees offered some recommendations for changes that could help to control dengue fever in Jeddah City, including the need for proper environmental planning and control. The next section reports on how the interviewees understood the Control Strategies.

6.4 The operational strategies for dengue fever control in Jeddah City

The operational strategies for dengue fever in Jeddah City was one of the main topics addressed by interviewees and one of the main themes of the analysis.

All the interviewees knew that in 2006, after the dengue outbreak in Jeddah City that year, the Government of Saudi Arabia gave an order to the Ministry of Health, the Jeddah Municipality, and the Ministry of Agriculture to take measures to control dengue fever in the City. They also all knew that the lead agency for that project was the Jeddah Municipality (General Department of Crisis and Emergency). An interviewee said, "The Ministry of Health, Jeddah Municipality, and Ministry of Agriculture are working together to fight dengue fever in Jeddah City and each one of them has different tasks and sometimes they work on some projects together" (Interviewee, 4).

The following paragraphs discuss the responsibilities of each agency, as reported by interviewees.

The Ministry of Health has a number of roles in dengue control. It undertakes a surveillance role; it reports the cases and sends them weekly to the Jeddah Municipality, and Ministry of Agriculture. This is typically the first step after the case goes to the hospital and the blood is analysed. One interviewee said: "The Ministry of Health is responsible for the medical help and sharing the information data for the dengue fever cases with the Jeddah Municipality, and Ministry of Agriculture" (interviewee, 15).

The Ministry of Health needs to assess the risk in Jeddah City neighbourhoods accurately, by understanding the data they have and analysing it so that operational activity can be planned effectively. It was noted by one interviewee that there was no dedicated research centre in Jeddah for dengue fever control and that anyone interested in research had to undertake this on their own, without the support of a centre.

It was also reported that sometimes the Ministry of Health staff work in the field with the Jeddah Municipal services. This may occur when Jeddah Municipality personnel go to people's houses to spray, and sometimes other personnel from the Municipality and Ministry accompany them in order to educate the people who are living in the house. This is consistent with the wider role of the Ministry of Health in community education, with the Ministry often also working in public places such as shopping centres, providing information and education to local people.

After the Ministry of Health sends the dengue fever data to Jeddah Municipality and the Ministry of Agriculture, those organisations use the information to plan their main task of controlling dengue fever by controlling the mosquitoes. The Jeddah Municipality is responsible for controlling mosquitoes inside Jeddah City limits, and the Ministry of Agriculture performs similar functions outside the city limits.

Jeddah Municipality has two sub-departments involved in dengue control; one is responsible for fighting mosquitoes inside homes, and the other is responsible for tackling mosquitoes outside houses. The first sub-department's project is called the *Home to Home* project to fight the mosquitoes inside the houses. This was discussed as part of the Strategies in Chapter 3 and its limitations noted because of cultural factors in section 6.3 above.

One interviewee explained how global positioning techniques had been used to identify locations and contribute data to a GIS project:

> "Jeddah Municipality works in Jeddah City neighbourhoods and goes from house to house to kill the *Ae. aegypti* mosquitoes. They take the GPS points for the dengue fever to know the residence location cases after they get the contact information from the Ministry of Health" (Interviewee 2).

As already noted, this contact information is not always accurate or complete.

The other sub-department has project work devoted to fighting the mosquitoes outside houses. This work is contracted to *Dalh*, a private company, and monitored by the Jeddah Municipal Laboratory. After *Dalh* sprays, the Jeddah Municipality Laboratory puts out traps and evaluates how effective the spraying has been by determining the number of mosquitoes they find, and whether the density of *Ae. aegypti* mosquitoes has decreased or increased. An interviewee described how the Municipal Laboratory provided additional information for control:

> "Their job also involves finding the hot spots for the *Ae. aegypti* mosquitoes by using the GPS points for the traps and analysing it with ArcGIS, reporting all the locations of the high densities of *Ae. aegypti* mosquitoes and sending them to the General Department of Crisis and Emergency so that their team can fight the mosquitoes outside and inside the houses" (Interviewee, 9).

The Ministry of Agriculture normally undertakes aerial spraying outside the Jeddah City's limits. It was reported that in 2009, after the flood in Jeddah City, that the Ministry of Agriculture also had to work inside the city limits as there were so many mosquitoes. One interviewee reported that in this the Ministry of Agriculture was every effective:

> "After the flood in 2009 there were more than 50,000 mosquitoes and for that reason they felt they had to use phosphorus pesticides. In the first week they had very good results which saw about 90% of the mosquitoes killed" (Interviewee, 11).

Staff from the Ministry of Agriculture were not generally aware of the overall Control Strategies being implemented by the Jeddah Municipality and Ministry of Health because their role is outside of the city limits and they have little need to focus on work within the city. They are, however, ready to provide any help if it is needed.

6.5 Progress of implementation

The progress of implementation for the Strategies to control dengue fever in Jeddah City has four important sub-themes for understanding how implementation has been progressing:

a) Relationship between the Ministry of Health, Jeddah Municipality, and the Ministry of Agriculture in dengue fever Control Strategies projects.

Almost all the interviewees reported that in the early stages of the Strategies the relationship between the Ministry of Health, Jeddah Municipality, and Ministry of Agriculture had been quite strong and they had worked collaboratively. In particular, they held regular meetings and worked together to develop good Strategies.

Interviewees also reported that these organisations no longer appeared to have such a close relationship, and that perhaps they work together less frequently than before. Some interviewees felt that this may have started after Jeddah City had a very bad flood in 2009 although the reasons for the weakening of the working relationship were not completely clear. Some of the interviewees speculated that poor control over the flooding was the main reason for any tensions that may have been among them. As one person stated:

> "About the relationship between the Ministry of Health, Ministry Agriculture and the Jeddah Municipality, it had all been good until 2009 before the flood, but there has been little contact after that and the reason for that is unknown and probably because the Government began to watch all the [flood, dengue fever control and other] projects that were happening in Jeddah City very closely after the flood due to many failed [flood, dengue control and other] projects. The flood showed how these projects were done badly and caused too many fatalities At that time, the Ministry of Health, Jeddah Municipality and the Ministry of Agriculture suddenly became very independent and very careful in doing their job" (Interviewee, 7).

As a result, it was noted that the Ministry of Health and the Jeddah Municipality did not share their data nor communicate with each other as much as they had prior to 2009, and that the Ministry of Agriculture only met with the other organisations during the Hajj season. One interviewee commented:

> "Right now, the Ministry of Health does not want to give all the information about dengue fever cases because the Ministry of Health think they own the data. This always happened between Jeddah Municipality and the Ministry of Health. Before 2009 they had many successful meetings, but now they do not have as many. The Ministry of Health and the Jeddah Municipality accept it as it is right now and there has been a very big gap between them ever since 2009. There are people who were

working in Jeddah Municipality that were fired, and some good people have started working right now. We hope that better leadership will help all the projects that were stopped with the Ministry of Health to start again, and we are seeing that, but it is very slow" (Interviewee, 3).

b) Worker roles and flexibility

The participants interviewed for this research have a range of different duties, depending on the organisation they work for and their role within it. The Ministry of Health interviewees reported that their flexibility to work was good, but they needed to have clear strategies and plans, as well as the ability to follow them. Some felt that their situation was clear and worked well, for example, working with a committee and making collective decisions.

As noted in Chapter 3, Jeddah Municipality had a wider range of roles and larger workforce dealing with dengue fever than the other two agencies. The interviewees in the Jeddah Municipality stated that their duties within their projects were not always clear but that they had a variety of experiences regarding their jobs and tasks, depending on their particular positions. One of the interviewees said "In my job I often find myself working on different projects because my boss saw that I needed to fill a gap" (Interviewee, 2). The interviewees working in the Jeddah Municipality reported that they have generally had considerable freedom to take action, except for one who reported that he really does not have great freedom because he has a particular, single task that he is required to complete.

Ministry of Agriculture workers appeared to have clear job requirements but also had certain flexibility. One interviewee said that there was need for close consultation with their manager if any deviation from existing plans was required because mistakes could compromise the overall success of a project. The roles and flexibility of the workers vary because of the nature of the roles of the three agencies. The responsibilities of the Jeddah Municipality are very complex and diverse, so there is greater diversity in the workforce and roles as well as higher levels of uncertainty.

c) Community and worker awareness of dengue

Most interviewees did not believe that the community was well informed about dengue fever. Most also thought that the Government could provide more education to raise awareness of dengue fever, so that people can be informed about the dangers and know what steps to take. Respondents believed that people in Saudi Arabia thought that dengue fever was just a normal type of cold. One interviewee said that when he tried to raise awareness among people, they said in Arabic "Rabna al hafiz," which means that "whatever happens to us from God is OK; the people accept it and God will also protect them because the culture and the background religion gave them that belief." Most of the interviewees in the Jeddah Municipality made similar comments about education: that the people need better education and awareness.

With respect to knowledge and awareness among workers, individual interviewees reported different perspectives on the seriousness of the dengue problem. One former project leader reported that there were too many people working on dengue fever projects, including some senior people, who do not themselves have a good educational background related to dengue fever, and they really should not be in their position. One interviewee said that "dengue fever is not really a crisis" because that interviewee thinks the number of cases is not really high compared to other countries that have this problem, but in contrast, another interviewee said:

> "Dengue fever in Jeddah City is a problem that can kill people and nothing has put Jeddah City at risk like what we have now. Dengue fever is a big problem everywhere around the world and Jeddah City is one example of what we have now and what we will expect of increasing dengue fever cases in a few years" (Interviewee, 12).

A number of the interviewees report that dengue fever workers need to have more training in the field, and more workers are required because the population density in Jeddah City is high. Another interviewee suggested that more people were needed, especially in the *Home to Home* project, with the work force needing to be increase from about 400 to 1,000. A few interviewees said some projects were not supervised well and suggested further training and more academic study.

d) Funding and resources

A number of interviewees were aware that the Saudi Government had allocated one and a half billion Saudi Riyals (approximately NZD 40 million) to the Ministry of Health, Jeddah Municipality, and Ministry of Agriculture to be used for dengue control. This was perceived by several interviewees to be an inadequate amount when shared among three agencies over a three year time frame. One interviewee noted that they “needed more money and were planning to do a lot of work, but they could not do it without any money” (Interviewee, 15).

At the time the interviews took place there was considerable uncertainty about the stability of the now increasingly expert workforce in the *Home to Home* project in Jeddah City. This was explained:

> “Jeddah Municipality is planning to fire about 280 people who are working on the *Home to Home* project because they cannot afford to pay them, and all of them are working on contract. There is also a group of these people in the same *Home to Home* project who managed to get official permanent jobs with the Jeddah Municipality after being in the contract for a long time. It is really hard to get a permanent job and have the Government pay them, not from the project money. These people who they are going to fire are experts because they have trained and spent much time working with dengue fever. Those workers will be lost, even the people who have got an official permanent job will be reassigned to other work” (Interviewee, 3).

With reference to the aerial spraying programme, one of the interviewees reported a need, at that time, to strengthen the resources for this work. This included a better area for landing the airplanes at the airport, and improvements to some of the basic airport services, such as a reliable electrical power supply. The airport uses a power generator and it was reported that sometimes there is not enough power to mix the chemicals or pesticides or enough light to see. A wall around the airport is needed, servicing for airplanes, more pilots, and special devices in the airplane to control the spray are also necessary.

The interviewees acknowledged the importance of the initial funding but they were clearly concerned that particularly the core operational work in Jeddah city was not well resourced or sustained. Without the proper resources, their work may not be effective in combatting dengue fever.

6.6 Overall view of the Government Strategies

This section provides an overview of the dengue fever Control Strategies as reported by the key informant interviewees and as commented on earlier in this chapter. While this research does not attempt a comprehensive evaluation, several interviewees responded to the invitation to make general comments on the overall design and effectiveness of the Strategies, and these are reported here.

In Chapter 3 (section 3.6) the Control Strategies for dengue fever in Jeddah City by the Jeddah Municipality, Ministry of Health and Ministry of Agriculture were presented. It was noted that they were well designed and consistent with WHO best practice of the time. Even so the level of dengue fever cases from 2007-2009 still gives cause for concern. The views of interviewees on the overall design and effectiveness are covered briefly below, followed by an analysis of their views on the progress of implementation of the Strategies.

Design and effectiveness of the Strategies

Most of the interviewees reported that the Government Strategies were very good, and they were fully in agreement with them. One of the interviewees said, "In my opinion, the Strategies are quite good" (Interviewee, 2). Another interviewee mentioned about the way in which the Government Strategies for dengue control were designed with the assistance of people educated and well informed about the problem. This interviewee stated that "the control strategies were designed by people who have a very good knowledge and education about dengue fever, and one of these people who has WHO experience helped to improve the Strategies" (Interviewee, 3).

In terms of the effectiveness of the Strategies in controlling dengue fever, informants reported a variety of views. Some indicated that the Strategies were not having the impact on dengue fever that had been hoped. The interviewees did make some positive points about the Strategies, and they wanted to see some changes that would improve the implementation, but there was a general view that no great change had taken place since 2006 when the Strategies were first put into place.

Some interviewees reported that the Strategies used to combat dengue fever were not adequate. Many people had been optimistic that after the dengue control projects began in 2006, and the good results of 2007, that the crisis was over and that the control Strategies were effective. Since then the number of cases had risen again and the interviewees felt there needed to be other measures put in place.

Interviewees had disparate views on the work of the Jeddah Municipality, from strongly endorsing the progress of the Strategies to saying that the efforts were a "waste of time". One interviewee was unsure about how effective the Strategies were in reducing dengue fever cases. This interviewee explained:

> "I believe what the Jeddah Municipality is doing and others is just for the media because they just want to show off their work to the Government via the media and there are too many things in the media that are talking about the dengue fever project, but no one said whether the number of the cases is decreasing as a result of the good work" (Interviewee, 10).

Implementation overview and barriers to effectiveness

Several interviewees said the implementation Strategies were poor and could be better, and they expressed concern about what was happening in some projects. Interviewees noted that eleven projects are now being run by the Jeddah Municipality, but it is not always clear what exactly the Jeddah Municipality was doing because the people working on these projects do not always have clearly defined roles. Sometimes they are told to work on different projects without prior notice which may mean that they do not have enough knowledge about the project or cannot talk about it due to high confidentiality. Several interviewees were unaware of some projects such as the balanced score card project and work force management system project. These two projects, while part of the Government Strategies were not mentioned by any interviewee.

One barrier to effective implementation has been the way in which the Jeddah Municipality, Ministry of Health, and Ministry of Agriculture work together or the extent to which they should work independently on any particular project. One interviewee reported, "I think we need to see the Ministry of Agriculture and the Jeddah Municipality work together inside the city to control the mosquitoes, but for some reason the Jeddah Municipality took that job away from the Ministry of Agriculture" (Interviewee, 10).

Another interviewee revealed that while his opinion about the Strategies was quite positive, he felt that the Strategies were not all well implemented. The laboratory was very good but the other projects, such as changing the window screens as part of the *Home to Home* project were not good. The work was too complicated and there was too much confusion with people doing several projects at the same time.

Overall, there was a very positive view of the laboratory work undertaken for the control project. One of the important things the Ministry of Health is doing is the analysis of blood samples. It was reported that the Ministry does not use a rapid test because it is not reliable, but this means that the diagnostic test takes longer. Some dengue patients will be very sick and, with the normal test taking about 48 hours to get the final result, these patients may be at greater risk.

Inadequate community and worker education and awareness were identified as important factors in preventing the Strategies from being implemented effectively. Several interviewees said that people in Saudi Arabia do not take dengue fever seriously and treat it like a normal cold and no more.

Even among staff working on dengue fever there is some reluctance to recognise the severity of the problem. The interviewees commented that perhaps because the Government Strategies had had a good result in 2007, people perhaps became too complacent and less conscientious. Even one project leader who was interviewed believes dengue fever is not really a crisis. Most of the interviewees, however, agreed that dengue fever remains a major problem in Jeddah City and that workers need more training and that the community needs more education to understand its importance.

Interviewees generally agreed that there is definitely a continuing need to control dengue fever at all times but understand that it is a difficult task because dengue fever is very hard to stop altogether. Nevertheless, the interviewees stressed that the dengue fever project must continue into the future.

Appropriate funding resources were also considered to be an important factor by many respondents. In 2006 the Saudi Arabian Government gave NZD 40 million (equivalent) to the Ministry of Health, Jeddah Municipality, and Ministry of Agriculture but that money was sufficient for only one year, and since then the three organisations have not had sufficient financial resources. The Ministry of Health, for example, had to spread that money over a period of three years while the Jeddah Municipality had problems with the *Home to Home* project because they could not afford to pay the workers their salaries and had to make them redundant.

Good research and analysis is vital to effective implementation and some interviewees commented that there was not enough research capacity in Jeddah City. It was noted that there is no local research centre to coordinate efforts, with those interested in research working in isolation and because they are self-motivated to do that work. One interviewee commented:

> "The Jeddah Municipality should focus more on the future, do more research study and not just work in the present. They should also use the data they have and analyse it and do some modelling because whatever they are doing right now is just for nothing. They need to analyse the data, focus on the future and formulate a long term plan to control dengue fever in Jeddah City. We hope we will be lucky and not see more cases in the future if they consider it as a serious work plan" (Interviewee, 2).

6.7 Summary

This chapter has examined the Control Strategies for dengue fever in Jeddah City and has identified five main themes. The first theme reported on the people who are working on dengue fever projects and noted that they had different levels of background or education with some without appropriate educational background, including some in senior positions.

The second theme was about the knowledge of dengue fever in Saudi Arabia and Jeddah City. Most of the interviewees understood that dengue fever is a major problem, concentrated in Jeddah City, particularly in the city centre. Interviewees also identified the main causes for the persistence of dengue, including a shortage of water, and climate and environmental problems, as has been identified in research literature. They also reported that cultural factors also inhibit effective control, particularly in relation to locating the residences of identified cases and limiting work access to private houses for control purposes.

The third main theme concerned the operational Strategies for dengue fever in Jeddah City. The Ministry of Health, the Jeddah Municipality, and the Ministry of Agriculture each undertake specific aspects of the Control Strategies. The Ministry of Health provides medical services, surveillance, and community education for the population. The job of the Jeddah Municipality was to control dengue fever inside Jeddah City both inside houses, for example the *Home to Home* project and outside by spraying, trapping, and controlling mosquitoes in the environment. The Ministry of Agriculture worked outside the city limits with aerial spraying and also sometimes helped the Jeddah Municipality inside the city limits.

The fourth main theme reported on the progress of implementation of the Control Strategies in Jeddah City. Most interviewees agreed that the relationship among the three agencies was strong in the beginning, but after the flood in 2009 the relationships became strained. In the second sub-theme interviewees from the Jeddah Municipality, Ministry of Health, and the Ministry of Agriculture said that sometimes their duties were quite unclear. Interviewees also commented on other aspects of implementation such as community education and awareness and funding of resources.

With respect to the fifth theme, which focused on overall view of Government Strategies, the interviewees had differing opinions. Some of the interviewees hold the opinion that whatever has been happening now to control dengue fever in Jeddah City has not proved very effective because the Strategies were not well implemented. Furthermore, there is neither research conducted nor consideration for the future. They have just been focusing on what they have now. It must be taken into consideration that these 15 selected informants are not a representative sample, and their views cannot be generalised to the wider workplace and management levels.

Given these reservations, the next chapter discusses the results of the qualitative analysis from this chapter as well as the quantitative analysis from Chapter 5 and how these analyses together can be understood in terms of the objectives of the aims and objectives of the thesis.

Chapter 7: Discussion

7.1 Introduction

Dengue fever has presented problems worldwide, with the WHO responding with policy development through its Global Strategy for Dengue Prevention and Control 2012-2020 (WHO, 2012). The purpose of this chapter is to discuss how the research objectives of this thesis, which have been framed in the light of the conceptual frameworks of the technical elements and enabling factors of the WHO Global Strategy for Dengue Prevention and Control 2012-2020 have been achieved. The three research objectives are discussed below (section 7.2), along with contributions of the research, its limitations and suggestions for the future.

7.2 Research aim and objectives

The aim of this chapter is to integrate the results from the two different methodologies (qualitative and quantitative) and to discuss the findings in relation to the thesis objectives. The overall aims of this research are to assess the social and physical environmental neighbourhood influences on the pattern of dengue fever, and make a preliminary determination of progress towards implementation.

Objectives

- To describe the spatial and temporal trends of dengue fever distribution in Saudi Arabia.
- To assess the relationship between neighbourhood physical and social environmental characteristics in Jeddah City and the distribution of dengue fever.
- To evaluate the response of relevant agencies to the problems of dengue fever in Jeddah City.

7.2.1 Objective 1: To describe the spatial and temporal trends of dengue fever in Saudi Arabia

Dengue fever cases in Saudi Arabia have risen significantly since 2004, from 343 documented cases to 3,350 in 2009. In 2006 and 2007 most of these involved Saudi nationals, but in 2008 the number of non-Saudi people contracting the disease increased to 56.0%. In 2009, however, the situation reversed and Saudi nationals again had 56.6% of the dengue fever cases. Non-Saudis represent only 30% of the population in Saudi Arabia, but have a much higher proportion of dengue fever cases than might be expected.

An investigation of the distribution of dengue fever cases in Saudi Arabia found the Makkah region to contain the highest number (97.9%) of total cases from 2006 to 2009, and most of these were concentrated in Jeddah City. Following the outbreak of dengue fever cases in Jeddah City in 2006 (1,308), the number of cases decreased in 2007 (243), but rose again in 2009 (1,606 cases). Furthermore, Makkah City, which in 2006 and 2007 had only 200 cases, rose to 1,697 in 2009. This indicates Makkah City as a new location with the potential to experience persistently high caseloads.

Dengue fever cases in the Makkah region pose risks for the entire country because case numbers have continued to rise since the 2006 outbreak. The Ministry of Health reported that in 2009 there were 3,328 dengue fever cases solely in the Makkah region but that by 2011 there had been a slight decrease of 1.3% to 3,240 cases (Ministry of Health, 2011). This was not the case with Jeddah City which had 2,182 cases in 2011, a significant increase of 57.6% from 2009. (Jeddah Municipality, 2012). The interviewees believe that Jazan City too also has a high number of dengue fever cases because it is near Yemen, which has a high number of dengue fever cases and poor health services. Without proper control, dengue fever has the potential to spread throughout Saudi Arabia.

One of the main reasons for the emergence of dengue fever in Jeddah and Makkah Cities is thought to be the number of pilgrims who, because there is no international airport in Makkah, first fly into Jeddah City and then continue by land to Makkah. Cross-border migration has been shown to be an important influence on the spread of dengue fever elsewhere. For example, one study revealed that German workers who visited Thailand had antibodies to the dengue virus when they returned to Germany (Jänisch et al., 1997). Another study found that the migrants from Italy, or Europeans living in Italy, who travelled to tropical countries, contributed to the number of dengue cases in Italy (Antinori et al., 2004). Those two examples show that dengue fever can spread from infected regions in the world to other regions which had not previously been infected. As Jeddah City is the main point of entry for pilgrims, dengue fever can be spread from tropical infected countries to Jeddah City.

International statistics claim that Saudi Arabia ranks among the largest recipient of international migrants after the U.S.A., the Russian Federation and Germany (Center for International and Regional Studies, 2011), but the presence of migrants in Saudi Arabia is seen as temporary. From September 2011, a voluntary policy called *Nitaqat* was introduced to start “Saudising” the workforce, a policy whereby Saudi residents were encouraged to join the workforce, and as a consequence one million illegal immigrants were forced to leave the country. Saudi Arabia has continued to work to reduce numbers of foreign workers and illegal residents and has tried to limit their presence. The scope and scale of the campaign has widened and some sources claim that another million deportations are underway (Françoise, 2014). Other things being equal, such policies are likely to limit the increase of dengue in Saudi Arabia.

In terms of the proportion of males and females within the Saudi and non-Saudi population, in Jeddah City and Saudi Arabia more widely, there was almost an equal number of each gender among the Saudis; however, in 2010 there were more non-Saudi males in Saudi Arabia at (68.0%) and in Jeddah City at (64.6%) than females. Males have a higher percentage of dengue fever cases than females, both in Jeddah City in Saudi Arabia. For example, in 2009, 62.3% of all Saudi cases and 82.5% of all non-Saudi cases were male. The ratio of males to females in 2009 was 2.46:1 in Saudi Arabia and in the same year, the ratio in Jeddah City was 3.37:1.This is higher than the ratios in studies from India and Singapore (Agarwal et al., 1999; Ray et al., 1999).

One of the likely reasons for the higher rate of male dengue fever cases is the Saudi cultural restriction on women which does not allow them the freedom of movement to drive or work far from their homes or families, so that they spend more time at home than men. This may have an impact on a woman’s exposure to any disease such as dengue fever. Furthermore, women tend to pay more attention to their health because they believe that if they become ill, their husband may take a second wife (Alyaemni et al., 2013). Males, on the other hand, because they are the main income earners, may travel and work wherever necessary, thus exposing themselves to the risk of contracting dengue (Mobaraki & Söderfeldt, 2010).

The highest proportion of dengue fever cases in Saudi Arabia is in the 15 – 44 age group and in Jeddah City in the 21 – 30 age group. These rates are higher than those shown in international studies from Bangladesh, Singapore and Indonesia (Goh, 1995; S. Halstead et al., 1970; Wali et al., 1999). Young and middle-aged adults in Saudi Arabia appear to be the ones most at risk of dengue fever. One possible reason may be that adults are generally more active in their travels and spend more time outside longer than children or elderly people do. Because this age group travels more, there is a greater likelihood of coming into contact with people who have been infected with dengue, and where there are people with dengue, the chances are greater that there are mosquitoes nearby that carry the disease, and hence a greater likelihood of transmission.

As data were compiled for this research objective, it became clear that Jeddah is the city that has been most affected by dengue fever in Saudi Arabia, and it could possibly have the highest number of cases in the Middle East. It is to the situation in Jeddah City that we now turn.

7.2.2 Objective 2: To assess the relationship between neighbourhood physical and social characteristics in Jeddah City and the distribution of dengue fever.

(1) The spatial distribution of dengue fever cases in Jeddah City neighbourhoods

The greatest number of dengue fever cases occurred in the centre and southern part of Jeddah, known as the “old Jeddah City”. Old Jeddah City has a high population and there are neighbourhoods with a significant percentage of foreign migrants living in poor conditions at high population densities. The interviewees for this research explained and agreed that these neighbourhoods became an ideal place for immigrants to live both because there is cheaper housing and also because of the opportunities for illegal non-Saudi persons to hide from the authorities. These patterns are similar to those found in the one other study of dengue in Jeddah which also showed dengue cases to be concentrated in the city centre and southern parts of the city (Alzahrani et al., 2013).

Neighbourhoods with a lower rate of dengue fever cases are located in the north of Jeddah City but even there every year more cases appear. The better environmental conditions and low population densities in the new neighbourhoods in the north could contribute to the low rate of dengue fever cases. Even so between 2006 and 2009, the distribution of dengue fever cases in Jeddah City neighbourhoods became more widespread and by 2009 dengue fever could be found almost everywhere in Jeddah.

(2) Is there evidence of spatial and temporal clustering of dengue fever in Jeddah?

Two different types of spatial and temporal analysis were used for this: hot spot analysis, and weekly data for the spatio-temporal analysis. Hot spot analysis was used to identify high and low hot spots of dengue fever cases and to examine their demographic characteristics. The high and low hotspots were statistically significant, and those neighbourhoods are highly clustered.

It is not surprising to find that there are different location and demographic characteristics for the high and low hot spot neighbourhoods in Jeddah City. The high hot spots of dengue fever cases were located in the centre and south (Old Jeddah City), while the low hot spots appeared in the north of the city. Neighbourhoods in Old Jeddah City are of a lower socioeconomic status than those in the north of the city. When comparisons were made between the demographic characteristics of the high and low hot spots it was found that high hot spots tended to have higher Saudi and non-Saudi sex ratios, greater population densities, and lower socioeconomic status than in the low hot spots. From this it would seem these neighbourhood attributes are important risk factors for dengue fever in Jeddah City.

The results for this thesis build on one other study of Jeddah City which attempted to model dengue fever risk based on socioeconomic parameters, nationality and age groups using GIS and remote sensing (Khormi and Kumar, 2011). This study found a similar result in that higher numbers of dengue fever cases occurred in poorer quality neighbourhoods (Khormi & Kumar, 2011). Unlike the present research the authors used satellite images to measure housing density, street width, and the roof area of the houses, as indicators of neighbourhood quality. However, the present research aimed for a better estimate of neighbourhood socioeconomic status. This was achieved using a Delphi method, with a checklist questionnaire sent to both experts and researchers who had a good knowledge of those neighbourhoods. To support the Delphi questionnaire results, the researcher visited some of those low socioeconomic status neighbourhoods and took photographs to complement the analysis. Khormi and Kumar, (2011) did not consult with experts in the area. They used satellite images, but were not able to specifically assess the socioeconomic status and the true conditions of the neighbourhoods, which may limit the application of their research.

Er et al. (2010) found dengue fever to be highly clustered in the Hulu Langat District of Selangor, near Kuala Lumpur in Malaysia. The study used a combination of GIS, spatial statistic tools, and demographic data, to determine the relationship between dengue cases and their spatial patterns. While they did not attempt to examine the demographic and social characteristics of their clusters, the latter were most evident in residential areas in Kajang, the district capital of Hulu Langat.

The present research also used weekly data for 2007-2009 to determine whether there was a subsequent spread of dengue fever from neighbourhoods, where major outbreaks occurred, to surrounding neighbourhoods. Neighbourhoods where major outbreaks occurred in 2006 and 2007, when measured on a weekly basis, were low income neighbourhoods located in the centre of the city, but in 2008 and in 2009 the neighbourhood with the largest number of (weekly) cases was located in the eastern part of Jeddah City. The distribution of dengue fever cases in Jeddah City neighbourhoods three weeks after the major peak week from 2006 to 2009 indicated new neighbourhoods affected in the north, particularly in 2009. Each year most of the affected neighbourhoods after the major peak week were located in Old Jeddah City. The distribution of dengue in the neighbourhoods for the three weeks following the major peak week revealed a new major peak week neighbourhood, which is similar to what occurred in 2008 and 2009. This significant change is an indication to neighbourhoods in the north as well as those least affected, that any neighbourhood could potentially exhibit a new major peak week if dengue fever cases spread widely in Jeddah City. This reinforces the point that any neighbourhood is at risk of dengue fever unless there are good Control Strategies.

Reports from interviewees in this research strongly supported the results of the hot spot analysis. They frequently mentioned that dengue is a problem in low socioeconomic status neighbourhoods in Jeddah City as well as among non-Saudi people living there. They were also deeply concerned about the spread of dengue fever to other Jeddah City neighbourhoods. The interviewees mentioned that the evidence for the cluster of dengue fever cases spreading in Jeddah City was because all those neighbourhoods have the same predisposition factors for dengue fever: high population density, low socioeconomic status neighbourhoods, and a high non-Saudi population.

(3) Explanations of Neighbourhood Variations in Dengue Fever

This section of the analysis aimed to examine the explanations for neighbourhood variations in dengue fever in Jeddah City neighbourhoods. The first analysis explored the relationship between dengue fever rates and the physical and social characteristics of Jeddah City neighbourhoods. Five explanatory variables (population density, percentage of non-Saudi people, sex ratio non-Saudi males per 100 females, sex ratio Saudi males per 100 females, and neighbourhood socioeconomic status) in Jeddah City neighbourhoods from 2006 to 2009 were examined. In 2006 low socioeconomic status was the only significant variable. In subsequent years, more variables became significant, and in 2008 all five variables were significant except for surface water conditions. The sex ratio of both Saudi and non-Saudi males per 100 females between 2007 and 2009 were consistently significant explanatory variables. This suggests that the pattern of dengue fever case rates has become more complex and that the gender ratio variables for Saudi and non-Saudi or the socioeconomic status variable on their own were not sufficient to explain neighbourhood variations in the incidence of the disease in subsequent years.

The results from the three stepwise regression models found that the Saudi sex ratio appeared in all the models as the most influential explanatory variable; however, the Saudi sex ratio alone cannot explain the pattern of dengue fever cases in Jeddah City because other explanatory variables also appeared. The combination between the explanatory variables may predict dengue fever cases.

In the first and second stages of the analysis, it was found that the Saudi and non-Saudi sex ratios were both consistent predictors of dengue case rates from 2007 to 2009. A plausible reason for the high positive correlation may be related to culture in Jeddah.

There are two points that can be made regarding the effects of culture on dengue in Jeddah City. First, culture appears to be influential because Saudi women, because of institutional gender discrimination, are largely forced to remain at home or close to home. Saudi women are not permitted to drive or to hold a job far from their home. As a consequence, of those in employment over the age of 15 years, 98.1% are male and only 1.9% are female (Central Department Of Statistics & Information, 2009). Women may not even travel outside the city limits without a male family member or getting the permission from the responsible male family member (Mobaraki & Söderfeldt, 2010). Because of this, the Saudi males are more active around the city and away from their homes for longer periods of time, including for employment and shopping (Alyaemni et al., 2013). Based on these culture and lifestyle reasons, both Saudi and non-Saudi men are most likely to be outside and in contact with others more than women, both Saudi and non-Saudi. Therefore Saudi and non-Saudi males are at a greater risk of contracting dengue fever.

Second, gender differences and the risk of dengue are accentuated by current Saudi attitudes towards work resulting in the country having an extremely high dependence on foreign workers, most of whom are male. There are few work opportunities for females (Françoise, 2014). Many non-Saudi people reside in high density areas such as the city centre where shopping centres are located, and where there is employment; only a few shops are managed by women and these cater for women's needs. Another example is that jobs predominantly occupied by non-Saudi men are in the automotive repair industry. As there is no public transportation in Jeddah, everyone must travel by car, resulting in a substantial repair industry. The majority of these workers are non-Saudi men. These two examples illustrate that the demand for non-Saudi workers is high and, because most of these workers are male, then immigration has reinforced gender differences in exposure to, and the prevalence of, dengue.

While gender differences between neighbourhoods were important predictors of dengue, so too was the influence of neighbourhood socioeconomic status which was a statistically significant predictor of the dengue fever case rate in 2006 and 2008 and overall for the period 2006-2009. It was not clear to what extent this factor reflected other neighbourhood characteristics.

Therefore partial correlation analysis was used to explore the different pathways by which neighbourhood socioeconomic status was linked to higher dengue case rates. Three possible pathways were explored consisting of the effects of neighbourhood population densities, the presence of migrant groups and the presence of distinct neighbourhood lifestyles/cultures. The neighbourhood population densities pathway suggested that the highest population densities can give the mosquito a chance to spread the disease among people. The presence of migrant groups was also a possible influence because the number of non-Saudi people was higher in poorer neighbourhoods. While the presence of non-Saudis was also related to the presence of more males, this was not a total explanation of the higher rates of dengue in poorer neighbourhoods given the independent effects of neighbourhood socioeconomic status. Third, the link between neighbourhood socioeconomic status and higher rates of dengue may also reflect the influence of local cultural factors, such as lack of education, or of future orientation, or distrust of Government officialdom, which will impede the introduction and limit the effectiveness of dengue Control Strategies.

The partial correlation analysis found that there was some evidence for all three pathways. The analysis showed the influence of non-Saudi people was more consistent than population density. Controlling for both factors significantly decreased the link between low socioeconomic status and dengue fever case rates as seen in 2008 and for 2006-2009. The fact that controls for population density and migrant status did not totally eliminate the link between neighbourhood socioeconomic status and dengue case rates suggests that a third pathway may be operative. This may reflect the fact that both Saudis and non-Saudis with limited education have a low understanding of the risks of dengue and may also both be more distrustful of Government officials seeking to enter their homes and control the disease. Much has been written about the urban underclass and cultures of poverty in the United States and Britain (Corburn, Curl, Arredondo, & Malagon, 2014; Lamont, Beljean, & Clair, 2014; Mac an Ghaill & Haywood, 2014; Mingione, 2008; Silver, 1993), and it is possible that similar socioeconomic characteristics are typical of poorer residents in Jeddah and may help explain the higher rates of dengue in poorer neighbourhoods.

The evaluation of sociocultural attitudes in relation to their effect on public health in Colombia by Suárez et al. (2009) illustrates well a situation where a cultural group is distrustful of Government officials. The qualitative results showed that the interviewees believe that because they are in the countryside they grow up strong and healthy and as natives to the region “animals, bugs and heat do not represent a risk”. In contrast, “visitors are regarded as weak or not physically and culturally fit to deal with the region’s maladies, such as dengue.” Because of the local attitude to dengue fever, interviewees said that they did not go to hospital unless they were bleeding and hence what could have been treated as a mild case of dengue fever is allowed to progress to haemorrhagic fever. In this situation local culture is at odds with a public health strategy that seeks to limit the spread of dengue in the local population (Suárez, González, Carrasquilla, & Quintero, 2009).

One cultural element noted by interviewees for this research is that culture has a limiting effect on spray control of *Ae. aegypti* in the home because in Saudi culture only men can respond to and open the door for public health workers. They also thought that people with low education were not particularly concerned about dengue fever because they do not understand the risk that dengue poses. It is difficult to reach this group to inform them about how to control dengue and recognise the symptoms, because they are not interested in understanding or protecting themselves. Interviewees thought that their lack of interest in education was part of their lifestyle/local culture and that this was a leading influence on dengue fever levels, particularly for those in low socioeconomic neighbourhoods. The interviewees mentioned they had witnessed non-Saudi people living in low socioeconomic neighbourhoods with poor environmental conditions, old houses with no air conditioning, and open windows that are hardly ever closed, which allow for the *Ae. aegypti* mosquitoes to easily enter the home.

While it is not possible in this thesis to determine the precise contribution of the different pathways, it is clear that the vulnerability to dengue fever is also affected by neighbourhood socioeconomic conditions. While few studies have explored the effects of neighbourhood socioeconomic status, the findings of the present research are supported by Hagenlocher et al.'s (2013) work in Cali City, Colombia. Using statistical and expert-based approaches to assess the vulnerability of the city, their findings showed high levels of vulnerability clustered in poor neighbourhoods with many young and illiterate residents and where there was both a high proportion of unemployed people and those who worked at home. These neighbourhoods with low socioeconomic status had a high population density as well as poor water infrastructure. Results were obtained by combining socioeconomic and demographic indicators (Hagenlocher et al., 2013).

The fourth analysis examined the effect of surface water on dengue. Surprisingly, there was no relationship between the amount of surface water and dengue fever case rates in Jeddah City. While there was some indication that poorer neighbourhoods had more surface water, this relationship was not significant.

Many international studies implicate surface water as an important factor in dengue fever cases. For example, Naghapakorn and Tripathi, (2005), in Thailand found there to be a significant relationship between dengue fever cases and bodies of water (Nakhapakorn & Tripathi, 2005).Through multivariate regression analysis and GIS based methodology, the influence of physio-environmental factors on dengue incidences were explored. The study showed that bodies of water posed significant risk for dengue fever in a district, while forest land had no influence at all (Nakhapakorn & Tripathi, 2005). The landscape discussed in that study is similar to that in Jeddah before the surface water problem was addressed.

The contrast between the findings of research into the relationship between surface water and dengue fever and the results of international studies is interesting. More surface water was present in the low socioeconomic status neighbourhoods as in Jeddah City neighbourhoods, which had high numbers of dengue fever cases, but unlike international studies there was no significant relationship with surface water in any of the years analysed. The lack of such a relationship may reflect the impact of Control Strategies in Jeddah City which have significantly decreased the amount of surface water since 2007. This was one of the objectives of the Control Strategies and seems to have worked well by reducing the impact of one important risk factor (Jeddah Municipality, 2009b). Interviewees reported that aspects of surface water had been relatively well controlled, particularly the large lakes, which may have had some impact on the lack of significant relationship between dengue cases and surface water.

This finding stands in contrast to international research on environmental justice issues which has shown that environmental conditions are usually worse in poorer and ethnic minority neighbourhoods (Stevenson et al., 2009; Tunstall, Shaw, & Dorling, 2004). In the United Kingdom, for example, Pearce et al. (2010) showed that poverty levels are positively associated with poorer quality physical environments. They also note that earlier research has tended to focus on a single environmental issue, rather than examining the complex array of environmental factors that may shape health outcomes, concluding that the physical environment is only one factor, and even then, not necessarily the most important one (J. R. Pearce, Richardson, Mitchell, & Shortt, 2010). Similarly Cummings et al. (2005) also found that there was a significant relationship between bad self-rated health and factors such as poor physical quality residential environments. The differences between these findings and the present research could arise because in Saudi Arabia public health officials have actively sought to limit the presence of source areas for mosquitos across Jeddah City as a whole, with the result that neighbourhood social differences in the presence of standing water are much less evident.

(4) The effect of climate factors on dengue fever case rates and how seasonal variations in dengue are related to neighbourhood social conditions.

Analyses of the impact of temperature and humidity factors on dengue in Jeddah City showed that more dengue cases occurred when the temperature was high and humidity was low. The weekly average of mean temperature and the weekly average of maximum, mean, and minimum humidity can affect the number of dengue fever cases more than the average maximum and minimum temperatures can because they were linear statistically and significantly with dengue fever cases from 2006-2009.

There have been a number of reviews of studies that have assessed the relationship between dengue fever and climatic conditions. There is consistent agreement that there is a relationship between climate and the incidence of dengue fever. For example Banu et al. (2011) reviews a number of studies which found that climate factors were important influences on the seasonal and geographical distribution of dengue fever cases (Banu, Hu, Hurst, & Tong, 2011).

Wu et al. (2007) studied the effects of weather variability on the occurrence of dengue fever in Kaohsiung in southern Taiwan. Using time-series analysis dengue fever was shown to be associated with variations in temperature and rainfall (Wu et al., 2007). Wu's study was similar to the current research because it found temperature to be an influential factor on dengue fever. In Jeddah City, the high temperatures and low humidity were the contributing factors. Wu's study differed from this thesis in that in Southern Taiwan rainfall is a contributing factor. This is not the case in Jeddah because the city has a very low rainfall and therefore rainfall data were not used.

This thesis shows that there is seasonal variation of dengue fever cases which varies markedly according to neighbourhood socioeconomic status. Low status neighbourhoods were far more likely to have an increased number of dengue fever cases in summer than middle and high status neighbourhoods. Moreover, relationship between the mean weekly temperature and humidity variables and the weekly dengue fever cases from 2006 - 2009 were mostly significant in the low and middle socioeconomic status neighbourhoods. The interviewees noted that the summer season is the prime time for dengue fever in Jeddah City when *Ae. aegypti* mosquitoes tend to go inside homes looking for cool places to rest. No other study has noted this relationship between seasonal variation, dengue, and the socioeconomic status of the neighbourhood.

7.2.3 Objective 3: To evaluate the strategic response of relevant agencies to the problems of dengue fever in Jeddah City.

The findings of the thematic analysis of the interviews, as reported in Chapter 6, identified five major themes: (1) Workforce characteristics and capability, (2) Knowledge of dengue fever in Saudi Arabia and Jeddah City, (3) Operational Strategies for dengue fever control in Jeddah City, (4) Progress of implementation and (5) Overall view of Government Strategies in Jeddah City. The findings from these are discussed below.

Theme 1: workforce characteristics and capability. Interviewees confirmed that many people working in dengue fever projects are not well qualified for their position. Several international studies on vector borne diseases and mosquito control programmes discuss the training of workers (Huang et al., 2011; Naranjo et al., 2014; Valarmathi & Parajulee, 2014). Naranjo et al. (2010) describe the training programme in Saint John's County in Florida where workers are required to have training to maintain their Florida Public Health Pesticide Applicators licence. The local mosquito control district provides training programmes and workshops throughout the year, allowing technicians to acquire the necessary credits to keep their licence. This includes specific knowledge based on new trends for mosquito control, calibration procedures, peak mosquito activity and ground and air application. Entomologists, educators, field workers and administrative staff are also trained. This ensures that resources, pesticides and knowledge of mosquito habitat development are used correctly. A study in Taiwan (Huang et al., 2011) researched health professionals' level of knowledge through a questionnaire survey, for the purposes of counselling travellers. Because Taiwan's dengue cases increased in 2009, the Government declared a four-year dengue fever plan with strategies for prevention of the disease. After analysing the results of the survey, researchers found poor levels of knowledge among the health workforce, and the Government has subsequently tried to strengthen education and training for the healthcare workers.

These two examples show that education and training are important for providing workers with the knowledge and skills they need to manage their work to a high standard. This is reflected in the identification of capacity building as an enabling factor for the WHO Global Strategy (WHO, 2012), and one which may have been neglected in the Jeddah City Strategies which does not mention any main objective related to the educational background and training for workers. Better professional education has been identified elsewhere as important for dengue control, and this may be a way for Jeddah City workers to be able to implement the Control Strategies in a more effective manner.

Theme 2: knowledge of dengue fever in Saudi Arabia and Jeddah City. This theme encompassed three sub-themes: a general understanding of the scope of dengue fever in Saudi Arabia and Jeddah City, the distribution of dengue fever in Jeddah City, and its persistence in the City.

For the first sub-theme, interviewees reflected a good general understanding of the scope of dengue fever in Saudi Arabia and Jeddah City. They highlighted the fact that other cities are infected also, such as Makkah, Qunfudah, Ta`if, Al-Madinah, Najran, and Al-lith and Jazan, but that is not always well recognised. The interviewees believed that after Jeddah, Makkah City was the next city likely to have an outbreak because of its proximity to Jeddah City and this was confirmed when this research found that the outbreak that occurred in Jeddah City in 2009 also affected Makkah City (Ministry of Health, 2009).

For the second sub-theme, the distribution of dengue fever in Jeddah City, the interviewees also believed dengue fever cases were continuing to spread every year to new places in Jeddah City, that since 2007 dengue fever cases had been increasing, an accurate view of the situation, and that the dengue Control Strategies in Jeddah must continue.

For the third sub-theme, the persistence of dengue fever in Jeddah City, interviewees suggested six main reasons for this: shortage of potable water and the need for households to store water, migration of non-Saudi people to Jeddah City, seasonal climate variation, environmental problems, cultural factors and the problem of rapid urbanisation.

In terms of potable water, international studies support this view (Biswas, Bhunia, & Basu, 2014; Dickin & Schuster-Wallace, 2014; Schmidt et al., 2011; Witaya Swaddiwudhipong et al., 1992). For example, a study in Tamil Nadu, South India, showed that the *Ae. aegypti* mosquito was found breeding near water containers. Because residents feared a lack of water supply, many households stored water in uncovered plastic containers or tanks which were in shaded areas and seldom cleaned, resulting in high mosquito breeding rates. The study concluded that preventive strategies need to be directed at minimising the breeding potential of *Ae. aegypti* as well as implementing better water management practices (J. J. Wilson & Sevarkodiyone, 2014).

The second reason for dengue transmission reported by interviewees is that the large number of non-Saudi people who arrive from around the world as pilgrims to Makkah City, through the international airport at Jeddah City. A large proportion of these (40%) come from countries of South and East Asia which are heavily infected with dengue fever (Tourism Information and Research, 2006). Most of the interviewees also knew that the first dengue fever case was a Yemeni male, and that Yemeni migrants tend to live in the older section of Jeddah City where poor conditions existed. In Madeira, which in 2012 had its first outbreak of dengue, a study was conducted to determine the origin of the dengue virus, focusing on air travel among dengue endemic countries and Madeira. The majority of travellers came from Venezuela and Brazil which had the highest dengue importation indices compared to other dengue endemic countries, and the virus responsible for that outbreak was most closely related to viruses circulating in Venezuela, Brazil and Colombia. The importation index is a good tool for recognising and predicting the most probable country of origin for importation of dengue into non-endemic countries (Wilder-Smith et al., 2014), and may offer potential for authorities in Saudi Arabia Jeddah to ascertain specific sources of risk.

A third reason cited for sustained dengue transmission is the seasonal climate variation factor. The interviewees reported that high humidity and high temperatures can provide good environmental conditions for the *Ae. aegypti* mosquito. While this may be an accurate view internationally, Objective two of this research found that high temperatures and low humidity are important in Jeddah City. The interviewees believed that the reason that the summer season in Jeddah City showed more cases of dengue fever than any other season is because the *Ae. aegypti* mosquito can survive for a long time in hot weather, and it tends to seek shelter and somewhere cool inside buildings, such as houses, markets and schools.

The fourth reason cited for dengue transmission involves environmental issues found in Jeddah City where there are areas of standing water. Jeddah City has two large lakes, Al Arbaeen and Al Mask, and they have the ability to host the *Ae. aegypti* mosquito. Some interviewees reported that the small areas of water around Jeddah City can also have an impact on dengue fever cases. In Jeddah City, dengue is no longer related to standing water because the work done on standing water has been effective and, according to the quantitative study, the presence of measurable standing water areas are no longer reasons for the persistence of dengue. Any urban water issues experienced in Jeddah City are likely to be more localised and due to local urban conditions.

In addition to the environmental problems, the fifth reason cited in the interviews for dengue transmission is the set of cultural factors in Jeddah City, which create barriers to people engaging with the authorities. The position of women involves the preference to withhold personal information. A study that provides an interesting comparative example was conducted in Trinidad and Tobago (Smith, 2012). The study used the Health Belief Model as a means of understanding public perception of a dengue fever prevention programme. Despite people's awareness of the preventive measures for dengue fever, a conscious effort to control it only took place when someone was affected by it. People needed to be convinced not to throw away water that had been treated with larvicide and to take responsibility for their own health. Smith also noted that women took an active role in all aspects of life and they played a dominant role, unlike women in Saudi culture. The authors concluded that the Health Belief Model did not adequately consider the role of culture and how decisions were made. The Trinidad and Tobago study showed that by understanding the sociocultural changes that affect behaviour, health problems, such as dengue fever, could be prevented (Smith, 2012).

The sixth reason cited for dengue transmission is rapid urbanisation. In the northern part of Jeddah City, where rapid urbanisation has occurred, informants reported an increase in dengue cases, confirmed by the quantitative analysis. There are many new buildings under construction there and as a consequence water is needed to mix cement. As a result, fresh water is often left standing, providing a breeding ground for the *Ae. aegypti* mosquito. Mulligan et al. (2012) provide additional insights into the problems or urbanisation and dengue fever from the planned city of Putrajaya, Malaysia. Connections between urban planning and dengue fever were examined. Mulligan et al. (2012) found that when new areas are planned, it is quite often the case that health and disease management are excluded from urban planning and governance. There was little consideration of environmental health issues in the urban policy and little interaction between public health officials and the planners of urban development. In Mulligan's study, dengue fever emerged because of the lack of relationship among the urban characteristics, processes and those responsible for urban development (Mulligan, Elliott, & Schuster-Wallace, 2012).

Jeddah has experienced similar consequences because the city's ecology and its predilection for dengue fever were not considered in the planning process. This suggests that public health advocacy, recommended by Global Strategy 2012-2020, is not fully present. Urban planners need to work along with health officials so that safe urbanisation can take place and dengue fever better managed or prevented.

Theme 3: outlined the operations of the three agencies responsible for the Control Strategies for dengue fever in Jeddah City: the Ministry of Health, the Jeddah Municipality, and the Ministry of Agriculture. The Ministry of Health provides medical assistance, community education, and also has a surveillance role, although no dedicated research centre. It works with the Jeddah Municipality to educate people already infected and the wider population through community education; although interviewees did not seem to think that this was very effective. This is discussed more fully under Theme Four below.

The second agency, the Jeddah Municipality, controls dengue fever inside Jeddah City's limits, both inside homes and outside. This *Home to Home* project encountered problems in achieving co-operation due to cultural barriers, as discussed above. The third agency, the Ministry of Agriculture, works primarily on spraying outside the Jeddah City limits, but assisted within the city at the time of the 2009 floods.

The operational Strategies for the three agencies are documented in the main guidelines for the Ministry of Health, the Jeddah Municipality and the Ministry of Agriculture (Jeddah Municipality, 2009b). It was clear that each agency needs to understand the work that is required and at times work on projects together. Furthermore, it was also clear that the designated lead agency for the Control Strategies was the Jeddah Municipality (General Department of Crisis and Emergency). It is an advantage that the guidelines for the operational Strategies for control of dengue fever in Jeddah City are well documented, and to a large extent reflect the technical requirements of the WHO Global Strategy, but clearly there are some problems with the actual implementation of the Control Strategies, as discussed under Theme 4, below.

Theme 4: set out some key sub-themes in the implementation of the Control Strategies: the relationship between the agencies; work roles and flexibility; community and worker awareness of dengue fever; and funding and resources.

The first sub-theme was about the relationship between the three agencies responsible for controlling dengue fever in Jeddah City; the Ministry of Health, Jeddah Municipality, and Ministry of Agriculture. Prior to 2009 this had been strong, but after the 2009 flood it weakened and the areas of responsibilities and duties became unclear. The reason for the change appears to be the close monitoring of projects by the Government with the consequence that the agencies became less collaborative, in their projects. Partnership, coordination, and collaboration, however, are enabling factors of the WHO Global Strategy and require the lead agency to work with other agencies to achieve a common goal. Typically, internationally the lead agency is the Ministry of Health for dengue prevention and control is the ministry of health (WHO, 2012), reflecting a clear top down approach to implementation. In this instance, however, the municipality, Jeddah City, appears to have been the lead agency. All agencies should share resources, especially in emergency situations, to mitigate an epidemic. The key to successful implementation of dengue fever control is inter-sectoral and intra-sectoral collaboration. Networking as an approach provides a platform for agencies to resolve cross and intra-agency issues as well as a way to reduce duplication of efforts (WHO, 2012). Spiegel et al., (2005) considered a series of case studies in Cuba, Guatemala, Singapore, Thailand, Indonesia and Vietnam and concluded that there can be only limited success for dengue fever prevention and control programmes where there is no community ownership or collaboration between community and government (Spiegel et al., 2005). Toledo et al., (2007) also noted the importance of collaboration and participation to achieving sustainability and a successful community-based dengue control programme (Toledo Romani et al., 2007).

The second sub-theme considered is work roles and flexibility. The roles and flexibility of the workers across the three agencies varied significantly and this led to tensions in relation to project progress. Jeddah Municipality is the lead agency for projects, with some roles and workforce provided by the other agencies. Jeddah Municipality, however, had organisational and resource problems and seemed unable to develop a coherent programme. In some instances there was a lack of flexibility and freedom to act because tasks were not clear, and some of the workers found themselves working on more than one project at a time. One of the interviewees attributed these problems to a lack of expert knowledge by field leaders; however, the issues in Jeddah Municipality are complicated by the large workforce and a more complex range of roles. The workers in the Ministry of Health were more satisfied with the scope and flexibility of their work, and the way it was managed, but wanted to see a clearer and better developed strategic plan. The Ministry of Agriculture workers had clear requirements but with a certain degree of flexibility.

There are also, however, some management problems in the Ministry of Agriculture which limit action and workers did not have the freedom to co-operate fully with the Ministry of Health, and the Jeddah Municipality This problem could have stemmed from the leadership of the Jeddah Municipality since they had main control of the Strategy.

The third sub-theme related to community and worker awareness of dengue fever. Dengue fever workers were reported to have a reasonably good knowledge and awareness of dengue fever, but it was suggested that improved community awareness is necessary. Interviewees suggested that Jeddah City residents thought dengue fever was simply a normal cold. Furthermore they believed that God would protect them and that whatever happened to them was the will of God and should therefore be accepted. Similar findings are evident in Patiala, India where Malhoutra and Kaur (2014), demonstrated the consequences of poor community understanding. They found that the majority of people understood that dengue was due to a mosquito bite; however, they had little knowledge about mosquito breeding habits and dengue fever symptoms. They tried to protect themselves from mosquitoes, but were unsuccessful because of their lack of knowledge of environmental control measures. The study recommended that the district health authorities develop large awareness campaigns in the community.

Examples of successful community education have been reported elsewhere (Hiscox et al., 2013; Kay et al., 2002; Nam, Kay, Thi Yen, Ryan, & Bektas, 2004; Wong, AbuBakar, & Chinna, 2014). Perez et al. (2007), for example, found after five years of evidence in a pilot study in Havana, Cuba that community-based control over *Ae. aegypti* can be possible. In order to be successful, dengue prevention needs to be approached as a social learning process which gives responsibility to the local people (Pérez et al., 2007), a characteristically bottom-up approach.

The Global Strategy 2012-2020 recognises the need for community education and better communication among those responsible for creating and implementing control programmes with the aid of the community. It notes that knowledge is required for action; however, knowledge alone may not be sufficient or persuasive enough to get the people to act. Communities need to be mobilised by educating them about source reduction, use of insecticides and use of health services in order to report dengue cases, and the willingness to accept dengue vaccination when recommended. In order to sustain and continue control measures, a more participatory approach is needed at the local level. Important decision makers need to communicate better with community leaders in order to utilise networks for responding to public health emergencies (WHO, 2012).

Funding and resources also limited the progress of the Control Strategies for dengue fever. In 2006, half a billion Saudi Riyals (SAR) (approximately NZD 40 million) were allocated to the three agencies to implement dengue Control Strategies for a three year period. After that period of time there was a problem with finance and, despite the need for continued efforts, the Jeddah Municipality had to fire about 280 people from the *Home to Home* project because they could not afford salaries. Other resourcing issues were evident, noted in the Global Strategy as an important enabling factor. For example, because the airfield does not have basic services, such as power or electricity, and relied on a power generator, there were difficulties with aerial spraying. The interviewees expressed concern about the impact that funding and resources problems had had on the Control Strategies overall.

Thus some of the limited progress in the implementation of the Control Strategy for Jeddah City may be attributed to problems in the relationship between the agencies, issues with work roles, community awareness of dengue fever, and funding and resourcing. A study by Nam et al. (2004) in Vietnam highlighted similar problems of implementation. The Ministry of Health in Vietnam had changed their approach from emergency response to taking preventive measures, but found it necessary to do both, which involved a substantial budget increase. Furthermore, it was essential for success that someone to take responsibility for developing community programmes, selecting and training health professionals and volunteers. Yearly evaluations and continuous monitoring of project impact, recommended enabling factors of the Global Strategy 2012-2020, were used to measure progress (Nam et al., 2004). The results from this study suggest that success is possible if a programme is well resourced, led, coordinated and monitored, and this may provide lessons for Jeddah City.

Theme 5: examines the overall view of Government Strategies in Jeddah City. Interviewees were positive about the overall approach of the Government to controlling dengue fever in Jeddah City and considered the design overall to be satisfactory. If the Strategies themselves are good, but the required results are not achieved, then, as interviewees noted, the problem is in implementation. The Strategy, however, was not completely aligned with the WHO Global Strategy (2012) and in particular it came up short on enabling factors, as noted above. There was probably insufficient planning or research to take into account requirements beyond the project's three year time frame. Had there been sufficient funding and other resources greater success could probably have been achieved. A more pro-active position to collaborate closely on the part of the Ministry of Health, Jeddah Municipality, and Ministry of Agriculture was also needed. One of the outcomes of this research is that it may be able to contribute to approaches whereby persistent ongoing problems are resolved and the Control Strategies for dengue fever are effective. This is further explored in the following sections.

7.3 Contribution of this Research

The strength of this study has been its ability to use mixed methods to investigate a number of aspects of dengue control in Jeddah City. The research has made a number of contributions that can be considered helpful. As there has been little research into dengue fever control in the Middle East, the results from this doctoral research may have particular relevance to this region. This research offers two main contributions to the control of dengue fever: the application of alternative methodologies and the new information obtained from the Jeddah City experience.

7.3.1 Methodology

Placing this research within the context of the Global Strategy 2012-2020 and a conceptual framework for policy and implementation provided an innovative but, highly relevant, approach to investigating dengue control in Jeddah City. In addition, this thesis study has made methodological contributions to the study of dengue fever by using mixed methods, Delphi analysis, pathways analysis, analysis of the climatic factors on the socioeconomic status neighbourhoods, in-depth interviews and weekly level analysis.

First, no previous study in the Middle East has examined dengue fever using a mixed methods approach. Such an approach is useful in order to understand the impact of neighbourhood risk factors of dengue and the extent to which these are related to existing Control Strategies. The mixed methods approach enabled aspects of both the technical elements and important enabling factors of the WHO Global Strategy for Dengue Prevention and Control, 2012-2020 to be examined, and this makes this research unique.

It has been suggested that using only one approach may be able to give a more detailed understanding of one aspect of a problem. Each aspect/question/problem may be best addressed by one method, but the same method may not be appropriate for the range of issues addressed in this thesis. For this reason a mixed methods approach for a study of dengue fever can be very helpful. By using both qualitative and quantitative method it is possible to obtain insights into broader ecological patterns and to gain a greater understanding of the factors which may be important in producing neighbourhood differences in the distribution of dengue. For example, after it was found through the quantitative analysis that the low socioeconomic status neighbourhoods in Jeddah City have the most dengue fever cases, the qualitative analysis of the interviews showed how cultural, educational, and migrant factors were important in explaining this pattern. This understanding can be helpful in evaluating dengue Control Strategies.

Second, because there is no official socioeconomic status measure in the census for Jeddah City, or any other Saudi City, the Delphi method was used to develop an alternative indicator of socioeconomic status for Jeddah City neighbourhoods which was then used in this research. This innovative approach was supported by on-site visits and photographs of Jeddah City neighbourhoods. The Delphi method could be used for developing consensus as a range of dengue control issues.

Third, while some other studies have examined the impact of neighbourhood social factors, the present research attempted to improve our understanding by analysing the possible alternative pathways by which neighbourhood socioeconomic status was linked to dengue case rates in Jeddah City neighbourhoods. It also made a small contribution by analysing the links between neighbourhood socioeconomic status, migrant status and gender. For both Saudis and especially non-Saudis, gender differences in dengue case rates were greatest in poorer neighbourhoods. This suggests the need for further studies which focus on interactions between key risk factors rather than treating them as independent variables.

Fourth, and similar to the point just made, prior to this research no studies have examined the links between climatic factors and neighbourhood socioeconomic status on dengue fever. Those studies that were found tended to examine the effects of both variables separately.

Fifth, a major feature of this study is the use of key informant interviews. These were instrumental in highlighting community aspects of dengue control and providing an initial overview evaluation of the Control Strategies. The evaluation commentary of the interviewees was wide ranging and, despite the limitations of qualitative studies, provided important insights that can be further researched. This was the first time that such work has been undertaken for dengue fever in Jeddah, and it is unusual in Saudi Arabia for officials to participate in research in this way. Providing confidence in the confidentiality of the research was an important element in securing participation.

The sixth contribution this study makes to dengue fever research was in using weekly case data in the analyses. The weekly level of analysis has not been used in any other study in the Middle East, with most studies using the much less detailed monthly or yearly data (Al-Ghamdi et al., 2009; Alharthy, 2007; Alshehri & Saeed, 2013; Fakeeh & Zaki, 2001; Ibrahim, Al-Bar, Kordey, & Al-Fakeeh, 2009; Mustafa et al., 2001; Saad et al., 2005).

7.3.2 Information for dengue fever control policies in Jeddah

This thesis has provided the context for the discussion of a range of new information regarding dengue fever in Jeddah City neighbourhoods, including the location of cases, gender ratios, the impact of socioeconomic status, culture and lifestyle, as well as the progress of Control Strategies. Dengue fever cases are mostly found in the old Jeddah district and south Jeddah City, and males are more likely to acquire dengue fever than females.

The research has led to a reappraisal of the role of surface water locally. It had been assumed that surface water in Jeddah City was a major contributor to the spread of dengue fever by harbouring mosquitoes; however, this research found that measurable areas of surface water had no relationship to dengue fever cases. The key informant interviews provided useful insights. They suggested that while the measurable surface water areas may not be important, the small areas of water created by urban conditions, such as construction sites or poor local waste-water disposal, may be important factors in the persistence of dengue fever.

The research provided new information to help understand the effectiveness of the current practices used for the control of dengue fever and where additional public policy initiatives are required. For example, improvements are needed in the quality of the urban environment, including domestic water supply and disposal, and the management of building works. Policy initiatives in migration management and community education were also noted.

The research reported new information on the detailed management of the dengue fever Control Strategies in Jeddah. While there are positive aspects, the implementation presented some problems, leading to some failures in the Strategies overall. The research found that the three agencies, the Ministry of Health, the Jeddah Municipality, and the Ministry of Agriculture, had different roles and responsibilities and that better co-ordination is required. The enabling factors identified by the WHO (2012) recommended that a Ministry of Health be given the opportunity to lead and manage the Control Strategies in a country widely affected by dengue fever (WHO, 2012), which is not the case in Jeddah City. The research also indicated that there was an absence of involvement of other agencies (e.g. primary care, education services) as suggested in the Global Strategy.

The research highlighted, particularly through the interviews, that, in addition to the serious problem of dengue fever in Jeddah City, dengue is also present in other cities such as Al-lith and Jazan, and that there is a need for early intervention to prevent its spread in those places.

7.4 Limitations of the research

This research relied on both quantitative and qualitative analysis, with each having its own limitations, discussed below. Limitations in the quantitative analysis relate to data sources and the time, level of detail, accuracy and effort required for data collection.

Accurate GPS points for dengue fever cases in Jeddah City were not available for all cases. This is unfortunate because had it been available it would have provided more accurate neighbourhood spatial analysis. Surface water data were not available for 2006 because the Jeddah Municipality only began tracking surface water from 2007. Access to earlier surface water data may have helped explain earlier outbreaks of dengue fever.

The accuracy and the level of census detail were important issues in this research. There was no continuous record for all neighbourhoods over time, only those ones for which 2004 was available. As a result, the neighbourhood analysis was based on a sub-set of data. Moreover, data were not available for the last census in 2010 and for this reason an estimated population for 2009 from Jeddah Urban Observatory was used. The specific details of the analyses showed the data as having different matching years for dengue fever cases from 2006 - 2009 analyses. For example, using the population data from 2009 for the four year analyses only matched with the 2009 year analysis. Lack of socioeconomic data in the census meant that the Delphi method had to be used to compile a neighbourhood socioeconomic measure. Incomplete census data limited the scope of the analysis despite the shortcomings.

Obtaining detailed information on dengue fever cases for 2006 - 2009 was a complex process, fraught with frustrations and delays and limitation of the research. It involved numerous dead-end e-mails and many face-to-face meetings over a six month period to find the right person who was willing to help and gather data that was requested. This not only led to much unscheduled work for the researcher, but also makes replication more difficult in a future study.

While the Delphi procedure for assessing the socioeconomic status of neighbourhoods was innovative, essential and worked well, it had some limitations. For logistical reasons the checklist questionnaire was kept simple, the number of respondents relatively few and the feedback process fairly rudimentary. It was supported by photographs of actual Jeddah City neighbourhoods, but taking photographs in low socioeconomic areas was problematic and created safety issues for the researcher. Many of those living in those areas may have felt offended if pictures of their home areas had been taken.

Limitations in the qualitative analysis were related to the restricted numbers of interviewees. This was due to time constraints and problems of access to potential participants. There was some difficulty in obtaining consent from potential participants. Of those who gave consent and were interviewed, there were concerns that some interviewees gave unclear or incomplete answers or would not talk about all of the issues. This is probably because of the lack of familiarity with such research and the reluctance of people from Saudi Arabia, an authoritarian society, to be critical of powerful institutions or have confidence in the anonymity of the process. It is unlikely that data saturation was achieved. More interviews could have helped in obtaining greater detail and therefore a more complete picture of the issues.

A more significant limitation of the study is that it was only able to review the implementation of an existing programme in Strategy for one city. While interviewees largely thought the Control Strategies were good, no information was sought on the wider policy context for dengue control in Saudi Arabia, and the interviewees selected were not necessarily suited to addressing this. The absence of a full analysis of dengue fever policy in the context of the WHO Global Framework, the experience of other countries and the aspirations of high level national stakeholders, and the identification of barriers to policy development is a limitation of this study.

7.5 Future directions

7.5.1 Future research

Unless the Government takes serious action to control dengue fever, as in Jeddah City, Saudi Arabia will have an increasing number of cases throughout the country. This doctoral study is well placed to provide guidance on the control of dengue fever, not only in Jeddah City, but also in Saudi Arabia, more generally. Consideration of the local social and physical neighbourhood environments and the performance of the Control Strategies can have an impact on dengue fever cases in Jeddah City and has applicability to other affected areas. Many research gaps still exist which can be filled if better data sources were available. Thus future studies of dengue fever in Jeddah City can potentially focus on several research projects. The following discussion highlights four possible projects which could be developed, in order of importance:(1) develop more comprehensive neighbourhood demographic and socioeconomic indicators which are risk factors for dengue, (2) examine the implementation of the Strategy in more detail, (3) investigate the role of culture/lifestyle and nationality factors, and (4) undertake research to support community education and compliance.

(1) Develop more comprehensive neighbourhood demographic and socioeconomic indicators which are risk factors for dengue

Perhaps the highest priority in terms of future research is the development of more comprehensive neighbourhood demographic and socioeconomic indicators which are risk factors for dengue. Ideally because conditions in Jeddah City are in a state of constant change, a temporal analysis of such indicators is also important. Such a research study could provide more accurate and recent environmental data which would help in the targeting of dengue control policies.

(2) Examine aspects of the implementation of the Strategies

This doctoral study has shown that there were problems in implementation of the Strategies and therefore the implementation process needs to be reviewed and improved. The three aspects of the implementation strategies that need refining are: co-operation between the agencies, workers' understanding the tasks for each project and evaluation of the Control Strategies for dengue fever. These can be achieved by ensuring that a greater number of respondents that cover a wider range of stakeholders participate in semi-structured interviews, more complex questionnaires that address specific indicators, and more complete feedback rounds.

The first aspect of this project is to examine co-operation between the agencies with the aim of developing a more effective and efficient Control Strategies. In-depth semi-structured interviews will indicate inter-agency co-operation, relationships and problems. These can be used to build a revised Control Strategies that is more collaborative and effective.

The second aspect is to use the different projects within the Control Strategies as the basis for questionnaires for workers to assess their understanding of their tasks. The results will be discussed with the interviewees so that the workers can add more detail about the task processes.

The third aspect of this project is to evaluate the current Control Strategies for dengue fever. Using the results from first and second parts of the project will help to develop a list of questions for the survey questionnaire to evaluate the Control Strategies. The survey questionnaire will cover all the Control Strategies projects. It is anticipated that interviewees will be honest in their responses because they have freedom to give their opinions and answer the questions posed in a confidential situation.

(3) Culture/lifestyle and gender factors

It is also suggested that culture/lifestyle and gender factors in Jeddah City neighbourhoods receive more attention in future research. These could be examined for both the Saudi and non-Saudi populations using survey questionnaires with a large number of participants. It would be helpful to learn more about daily life practices, cultural practices, and freedom and constraints on both men and women that may inhibit or encourage the spread of dengue fever. The results from this future study will help to understand how these factors may be pathways for dengue fever.

(4) Community education and compliance

The fourth research project is a survey of community knowledge of dengue and dengue control practices. This research has highlighted that there is a problem with community knowledge of dengue fever in Saudi Arabia and Jeddah City. Survey methods can be used to examine the levels of knowledge of dengue in a range of different communities, including Saudi and non-Saudi people, men and women, and people of different ages, and socioeconomic status, and, crucially, the extent to which those surveyed consider dengue fever to be a problem. This will provide insights that can lead to better and more targeted education approaches, and better control solutions.

(5) National dengue control policy in Saudi Arabia

Future research should also include examination of the need for a national dengue control policy for Saudi Arabia as a whole. This will require a qualitative study with interviews of senior policy makers, experts, and other key stakeholders. A project such as this will go some way to addressing the limitation of scope discussed above, in that a wider policy context for dengue fever control would form part of the scope for this research. From this a more comprehensive, National Strategy can be developed, one that is appropriate for the whole country and takes account not only of the Saudi Arabian context, but also the international context and situates it within the WHO Global Framework.

7.5.2 Future policy recommendations

This section highlights policy recommendations for supporting the control of dengue fever cases in Jeddah City:

The first policy recommendation is that census material from across Saudi Arabia, including data at the neighbourhood level, from time to time be made available for research purposes. This includes demographic and socioeconomic data.

The second policy recommendation is to recognise the key variables of socioeconomic status, gender and culture/lifestyle in detailed planning for dengue fever control, including at the neighbourhood level. This research showed that male dengue fever cases outnumber female cases. Knowledge such as this can give direction to Control Strategies because then the areas where men are generally gathered, such as markets and workplaces, can be identified and targeted. This does not mean that females are not at risk of dengue fever, but the risks are different. This must be properly research be considered and play a role in the development of a revised Control Strategies. Differing cultural and lifestyle factors for both Saudi and non-Saudi can be addressed through neighbourhood level planning to improve local physical environments and assist residents to understand issues related to dengue control. The voice of the people can contribute to the design of the Control Strategies because they are the ones who deal with the specifics of the culture and lifestyle on a daily basis.

The third policy recommendation is to develop a better community education and compliance programme. Residents' knowledge of dengue fever is limited, and of greater concern is that few seem to regard dengue fever as a serious health risk. The research project suggested above: Develop community education and compliance, must take into account the cultural and local neighbourhood characteristics. Hence, the Control Strategies must include a strong objective to educate people to a level which can help them to protect themselves.

A fourth policy recommendation is that there should be stronger public health advocacy in urban planning in Jeddah City and that public health and urban planners work closely together to ensure a safe environment.

The fifth policy recommendation is to review the governance and management of the Control Strategies in order to improve implementation. Good governance requires a high level of co-ordination and co-operation among the key stakeholders: Jeddah Municipality, the Ministry of Health, and the Ministry of Agriculture. Strong leadership is required by Jeddah Municipality to ensure that operational requirements can be met. Greater financial resourcing is required by central Government to enable the Control Strategies to be successful. Because the implementation of the Control Strategies implementation has not been completely successful the strategies need to be reviewed and updated with revised objectives and projects. Of importance is the timeframe for action. The experience from the 2006 dengue outbreak and Control Strategies implemented at the time suggest that a two year review is optimal. This is because the Control Strategies for dengue fever in 2006 had a strong impact the year following the outbreak. Since that time, however, the number of dengue fever cases has continued to rise, suggesting that frequent reassessment and revision of Strategies is required.

At a management level, for the Control Strategies to be effective and efficiently implemented, employees at all levels must have a better knowledge about dengue fever. This would enable the Strategies to be applied in the way that they were designed to be. One obvious recommendation is that all people or officials working on Control Strategies projects should receive substantial training and experts should be employed who can collaborate with different countries around the world.

The sixth policy recommendation involves a wider engagement with other agencies and groups such as the education sector, primary health care sector, the media and Hajj officials. Education about dengue can be communicated through the media and, in particular, through the new social networks, as these have shown good results with the community. Teaching about dengue fever at all education levels would also be a powerful tool in controlling dengue fever. This doctoral research showed that adults are the age group most affected by dengue fever, a fact that could be used to an advantage if young people are educated and therefore more able to take protective measures. Moreover, increasing the involvement and understanding of primary health care professionals will assist the community to obtain accurate information about dengue fever since it is one of the first places people go when they need assistance with symptoms. During the Hajj season, the pilgrims should be made aware of dengue fever and how to limit their risk factors, for example, the way that they use water and avoiding sleeping in infected outdoor areas.

The seventh policy recommendation points to the establishment of a research centre for dengue fever in Jeddah City. At present there is no dedicated research centre that can support the development and monitoring of a dengue Control Strategies and undertake a range of social research that can contribute to such a strategy. Such a centre could collaborate with the Dengue Fever Laboratory in Jeddah City.

7.6 Conclusion

Since 2007, the number of dengue fever cases has been steadily increasing, mainly because the social and physical environment of local neighbourhoods in Jeddah are hospitable to mosquitoes, and the inability of the dengue Control Strategies to have a major impact. The framework of the WHO Global Strategy for Dengue Prevention and Control, 2012-2020 will be useful for developing an updated Control Strategies for Jeddah City, but any new Control Strategies must be accompanied by local level analysis and planning, and take into account the enabling factors identified by WHO dengue control for Jeddah City is a local issue and must have stronger local co-ordination than at present, and be better supported by relevant enabling factors, including greater involvement of non-health agencies. It must also, however, be supported by strong policy leadership and resources from the Government. The local strategies must contain creative ideas to analyse and to plan strong strategies to control dengue fever in Jeddah City or any place that requires action at the local level. Effective strategies in Jeddah City, where the problem of dengue is most serious, can provide a model for other cities where the problem is emerging, both in Saudi Arabia and other parts of the region.

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Appendices

Appendix 1: Delphi questionnaire

ماهو المستوي الاجتماعية والاقتصادية لأحياء جدة في نظرك؟

مثال: حي غليل (منخفض-متوسط-عالي-لا أعلم) ارجو بقدر المتسطاع عدم اختيار لأ أعلم.

لمعرف امكان الأحياء يمكن الإستعانة بالخريطة المرفقة.

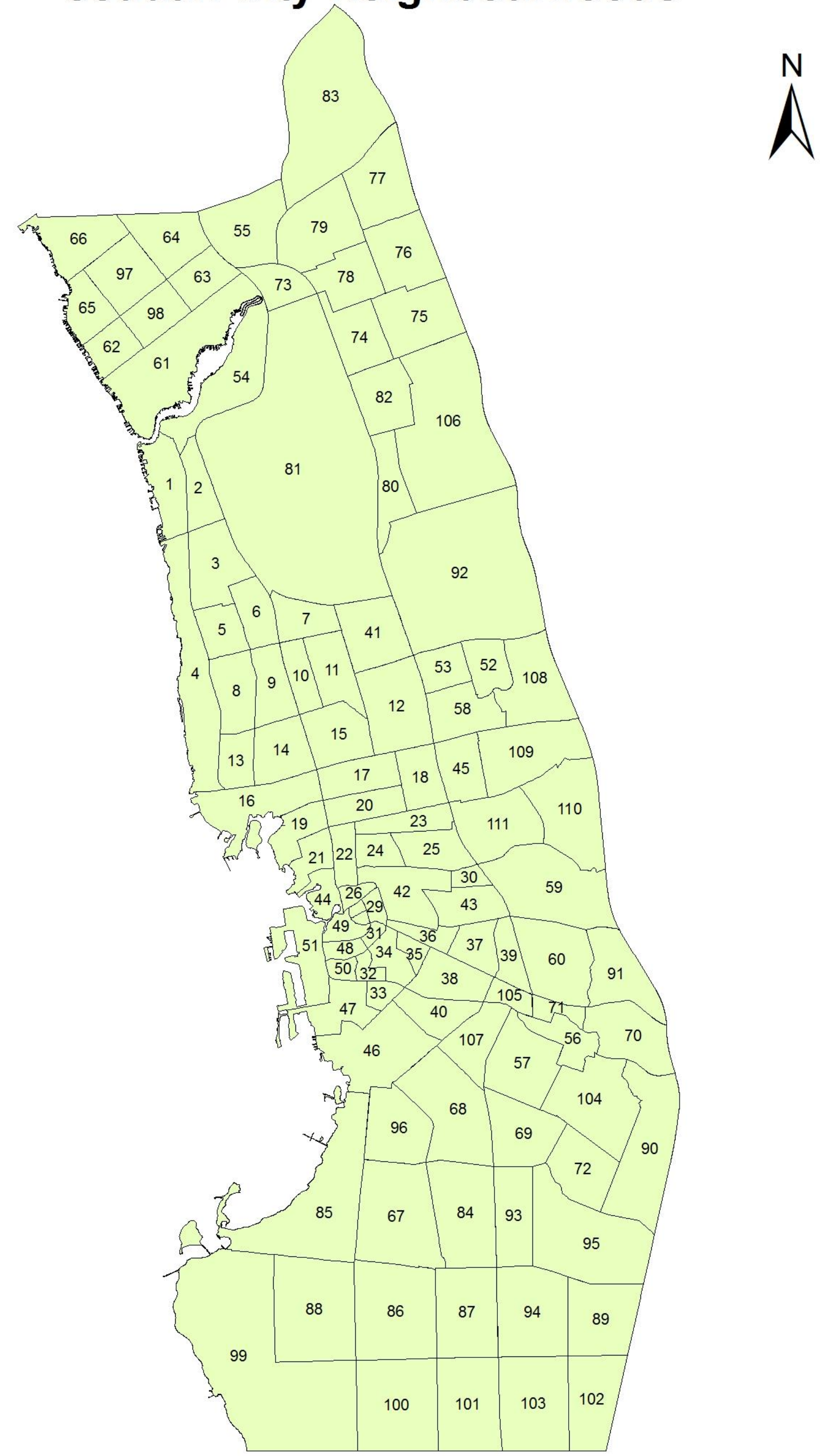
لمراسلة وارسال الاستمارة على :
ialkh@yahoo.com

رقم	الحي السكني	منخفض	متوسط	عالي	لا أعلم
1	المرجان				
2	البساتين				
3	المحمدية				
4	الشاطئ				
5	النهضة				
6	النعيم				
7	النزهة				
8	الزهراء				
9	السلامة				
10	البوادي				
11	الربوة				
12	الصفا				
13	الخالدية				
14	الروضة				
15	الفيصلية				
16	الأندلس				
17	العزيزية				
18	الرحاب				
19	الحمراء				
20	مشرفة				
21	الرويس				
22	الشرفية				
23	بني مالك				
24	الورد				
25	النسيم				
26	البغدادية الشرقية				
27	العمارية				
28	الصحيفة				

				الكندرة	29
				السلمانية	30
				السبيل	31
				القريات	32
				غليل	33
				النزلة اليمانية	34
				النزلة الشرقية	35
				الثغر	36
				الجامعة	37
				مدائن الفهد	38
				الروابي	39
				الوزيرية	40
				المروة	41
				الفيحاء	42
				جامعة الملك عبدالعزيز	43
				البغدادية الغربية	44
				الواحة	45
				المحجر	46
				بترومين	47
				الهنداوية	48
				البلد	49
				الثعلبة	50
				ميناء جدة الاسلامي	51
				الأجواد	52
				المنار	53
				ابحر الجنوبية	54
				طيبة	55
				الأمير فواز	56
				الأمير عبدالمجيد	57
				السامر	58
				الرغامة	59
				المنتزهات	60
				ابجر الشمالية	61
				الأمواج	62
				الفردوس	63
				الصوراي	64
				اللؤلؤ	65
				الزمورد	66
				السروات	67
				الصناعية	68
				السنابل	69
				الفهد	70
				العدل	71
				الهدى	72

73	الاصالة				
74	الحمدانية				
75	الصالحية				
76	الرحمانية				
77	الفروسية				
78	الفلاح				
79	البشاير				
80	الريان				
81	مطار الملك عبدالعزيز				
82	الكوثر				
83	الرياض				
84	الخمرة				
85	قاعدة الملك فيصل البحرية				
86	الضاحية				
87	القرينية				
88	الوادي				
89	الكرامة				
90	الشفا				
91	ام السلم				
92	بريمان				
93	التعاون				
94	الفضيلة				
95	التضامن				
96	السروية				
97	الياقوت				
98	الشراع				
99	الساحل				
100	المليساء				
101	المسرة				
102	الرحمة				
103	البركة				
104	الاجاويد				
105	الفاروق				
106	ام حبلين				
107	الجوهرة				
108	المنتزة				
109	الشروق				
110	مراخ				
111	النخيل				

Jeddah City Neighbourhoods



Appendix 2: Ethical approval

UC UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

HUMAN ETHICS COMMITTEE

Secretary, Lynda Griffioen
Email: human-ethics@canterbury.ac.nz

Ref: HEC 2012/23/LR-PS

28 September 2012

Ibrahim Ali Alkhaldy
Department of Geography
UNIVERSITY OF CANTERBURY

Dear Ibrahim

Thank you for forwarding to the Human Ethics Committee a copy of the low risk application you have recently made for your research proposal "A spatial analysis of Dengue Fever and analysis of prevention and control strategies in Jeddah, Saudi Arabia".

I am pleased to advise that this application has been reviewed and I confirm support of the Department's approval for this project.

With best wishes for your project.

Yours sincerely

pp L Griffioen

Lindsey MacDonald
Chair, Human Ethics Committee

University of Canterbury Private Bag 4800, Christchurch 8140, New Zealand. www.canterbury.ac.nz

E 8

Appendix 3: Information sheet

Appendix 1: Information Sheet

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Health Sciences Centre
University of Canterbury,
Private Bag 4800
Christchurch, New Zealand.
Tel: +64 3 366 7001 x8691, Fax: +64 3 364 3318

Information Sheet

Spatial Analysis of Dengue Fever and an Analysis of Prevention and Control Strategies in Jeddah, Saudi Arabia

Who is the researcher?
The researcher is a PhD student from the Geography Department and School of Health Sciences at the University of Canterbury in New Zealand. He has a scholarship from the King Abdullah Foreign Scholarship Program.

What is the research about?
This research investigates the spatial and temporal trends of dengue fever and the strategic and operational approaches of the Ministry of Health and the Jeddah Municipality to dengue fever control in Jeddah.

What do I expect from you?
For this research I need to interview people who are working or who have worked with the Ministry of Health and the Jeddah Municipality on dengue fever management in Saudi Arabia. The interview will take up to one hour and will be recorded, with your permission. You may withdraw from the interview at any time and your information will not be used in the project.

Will my interviews in this research be kept confidential?
Yes, every effort will be made to ensure the confidentiality of the participants. No personally identifiable information will be collected and no individual will be identified in the thesis. Access to the data is limited to the researcher and his supervisors.

What will happen to the results of this interview?
I will use the results from the interviews as a part of my thesis and it may be used for journal publications or conferences. The thesis will be a public document via the University of Canterbury library database. You will also be able to get a copy of the results from this research.

Who has reviewed this study?
This proposal has been reviewed and approved by the University of Canterbury Human Ethics Committee low risk process.

For any question you can contact Ibrahim Alkahldy (ibrahim.alkhald@pg.canterbury.ac.nz) or his supervisor, Associate Professor Pauline Barnett (pauline.barnett@canterbury.ac.nz

Appendix 4: Interview consent form

Appendix 2: Consent form

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Health Sciences Centre
University of Canterbury,
Private Bag 4800
Christchurch, New Zealand.
Tel: +64 3 366 7001 x8691, Fax: +64 3 364 3318

Interview Consent Form

Spatial Analysis of Dengue Fever and an Analysis of Prevention and Control Strategies in Jeddah, Saudi Arabia

1. I have read the Information Sheet, accept the terms of the interview, and I am happy to be interviewed.
2. I understand that the data resulting from this interview will be used by Ibrahim Alkhaldy in his PhD thesis.
3. I understand that the data might appear in publications or conference papers.
4. I understand that every effort will be made to ensure confidentiality and any identifying information will not be used in any presentations or reports, unless I specifically request it.
5. I understand that I am able to withdraw my consent and discontinue participation at any time from this interview.
6. I understand that the data will be held for 10 years before being destroyed.
7. I understand this interview will be recorded and I have the right to stop it at anytime.

Name: ______________________

Signed: ______________________

Date: ______________________

This proposal has been reviewed and approved by the University of Canterbury Human Ethics Committee low risk process.

For any question you can contact Ibrahim Alkahldy (ibrahim.alkhald@pg.canterbury.ac.nz) or his supervisor, Associate Professor Pauline Barnett (pauline.barnett@canterbury.ac.nz) Pauline Barnett (pauline.barnett@canterbury.ac.nz)

Appendix 5: Dengue fever cases per 10,000 populations in Jeddah City neighbourhoods, 2006–2009

ID	Neighbourhoods	2006	2007	2008	2009	Average 2006-09	SES levels
1	Al ameerfawaz	1.372	0.221	1.639	0.703	0.996	Mid
2	Al ammareih	0.659	1.907	12.273	11.847	6.865	Low
3	Al andulus	9.802	0.000	0.537	4.148	3.551	Mid
4	Al azizeiah	0.081	1.333	2.119	0.073	0.905	Low
5	Al bagdadeiah al garbeiah	11.465	0.738	14.955	32.994	15.391	Mid
6	Al bagdadeiah al sharqeiah	0.395	0.000	8.833	1.776	2.807	Mid
7	Al balad	1.722	0.923	5.431	2.097	2.651	Low
8	Al basateen	35.603	1.909	0.921	23.126	15.229	High
9	Al bawadi	0.380	0.734	1.062	0.228	0.600	Mid
10	Al faysaleiah	0.318	0.614	0.395	1.717	0.779	Mid
11	Al fiha	0.288	0.278	1.073	0.777	0.614	Low
12	Al hamrah	1.712	0.826	0.000	4.619	1.825	High
13	Al hendaweiah	9.846	2.281	9.742	6.629	7.190	Low
14	Al jameah	6.616	0.538	3.504	6.326	4.256	Low
15	Al jawharah	0.000	0.000	1.602	1.546	0.815	Mid
16	Al kandarah	4.446	0.817	10.258	4.951	5.166	Low
17	Al khalediah	0.644	1.866	1.201	2.318	1.527	Mid
18	Al khomrah	4.729	0.761	2.938	6.380	3.735	Low
19	Al mahgar	19.166	0.740	4.286	15.858	9.989	Low
20	Al malekabdoulazez airport	0.000	0.000	0.000	0.000	0.000	Mid
21	Al marjan	0.000	0.000	0.927	16.993	4.712	High
22	Al marwah	2.027	0.326	0.630	0.000	0.720	Mid
23	Al mohammadeiah	0.695	0.335	0.324	0.312	0.412	High
24	Al naeem	0.993	0.319	0.925	2.381	1.176	Mid
25	Al nahdah	0.328	0.317	0.917	1.180	0.699	High
26	Al naseem	3.369	0.591	1.998	2.755	2.177	Mid
27	Al nazlah al sharqeiah	25.649	0.387	0.000	2.883	6.931	Low
28	Al nazlah al yamaneiah	2.126	0.789	1.067	4.412	2.131	Low
29	Al nuzha	5.524	0.118	0.343	1.766	1.890	High
30	Al qryat	12.962	0.596	10.926	18.318	10.820	Low
31	Al rabwah	1.768	1.024	0.593	2.863	1.575	Low
32	Al rawabe	0.893	0.646	1.560	4.919	2.062	Low
33	Al rawdah	0.918	0.354	0.684	1.816	0.957	High
34	Al rehab	4.080	0.219	0.422	2.243	1.719	Mid
35	Al rughamah	1.328	0.285	0.825	2.918	1.363	Low
36	Al ruwase	6.184	0.181	1.397	2.022	2.397	Low
37	Al sabeel	25.244	0.343	8.944	2.238	8.928	Low
3	Al safa	1.239	0.622	0.923	2.986	1.467	Mid
83	Al sahefah	5.313	2.797	8.100	3.040	4.805	Low
9	Al salamah	0.268	0.259	0.250	0.964	0.444	Mid
40	Al senaeya	0.000	12.578	24.291	46.895	21.613	Low

41	Al sharafiah	2.267	1.094	2.716	4.078	2.571	Low
42	Al shate	1.310	0.000	0.305	0.000	0.388	High
43	Al sulaymaneiah	3.994	0.321	1.240	2.694	2.050	Mid
45	Al thagur	2.697	0.434	2.722	2.425	2.076	Low
46	Al thalebah	7.225	0.000	4.481	3.659	3.832	Low
47	Al worood	0.000	0.000	1.430	0.000	0.363	Mid
48	Al zahra	0.745	0.240	0.231	0.670	0.471	Mid
49	Bane malek	2.407	0.258	0.872	2.766	1.584	Low
50	Betrumeen	10.127	0.227	2.633	5.719	4.631	Low
51	Buraiman	2.961	0.000	0.558	2.153	1.406	Mid
52	Guleel	17.977	0.683	4.088	11.203	8.417	Low
53	Madaen al fahad	4.137	0.222	0.857	4.341	2.396	Low
54	Meshrefah	0.295	0.000	0.367	1.062	0.443	Low
55	Obhur al janoubeiah	3.869	0.000	0.000	0.000	0.917	Mid
56	Obhur al shamaliah	10.035	2.421	0.000	4.513	4.160	High

Sources: (Jeddah Municipality, 2012; Ministry of Health, 2010)

Appendix 6: Two and three kilometre buffer around the centre point in Jeddah City neighbourhoods

Neighbourhoods	Surface water Size in the Buffer by the Square Meter						SES levels
	Two Kilometre			Three Kilometre			
	2007	**2008**	**2009**	**2007**	**2008**	**2009**	
Al ameerfawaz	28,236	28,236	529	33,005	32,867	1131	Mid
Al ammareih	160	160	0	23,570	22,762	13,175	Low
Al andulus	1,098	1,098	7,338	9,134	6,284	7,338	Mid
Al azizeiah	5,471	1,794	1,721	11,014	2,549	6,211	Low
Al bagdadeiah al garbeiah	750	0	0	6,100	2,010	947	Mid
Al bagdadeiah al sharqeiah	750	0	0	24,933	23,971	23,984	Mid
Al balad	218	160	0	27,791	27,678	9,134	Low
Al basateen	6,666	0	0	75,590	66,249	66,241	High
Al bawadi	327	0	0	1,269	941	0	Mid
Al faysaleiah	6,847	1,364	1,592	9,895	1,456	2,243	Mid
Al fiha	21,252	21,252	22,011	27,289	23,499	30,081	Low
Al hamrah	494	282	2,905	11,323	6,242	4,504	High
Al hendaweiah	15,751	15,639	8,119	15,751	15,639	0	Low
Al jameah	13,375	0	0	15,499	0	306	Low
Al jawharah	13,818	13,818	0	28,248	28,180	54,095	Mid
Al kandarah	19,359	19,359	13,175	26,148	26,148	24,580	Low
Al khalediah	13,867	4,538	1,625	18,867	8,908	7,331	Mid
Al khomrah	831	831	0	25,138	25,138	30,376	Low
Al mahgar	95,150	95,100	496,012	137,438	136,488	666,918	Low
Al malekabdoulazez airport	26,106	26,106	8458	128,533	125,857	94,058	Mid
Al marjan	3,649	0	0	6,666	162,589	0	High
Al marwah	5,867	2,431	24,085	166,570	0	231,228	Mid
Al mohammadeiah	6,987	6,411	814	23,445	22,827	10,128	High
Al naeem	16,333	16,167	9,265	59,832	59,089	27,174	Mid
Al nahdah	39,584	38,841	17,299	43,003	42,261	17,407	High
Al naseem	7,078	1,787	5,280	14,050	8,759	52,138	Mid
Al nazlah al sharqeiah	14,280	14,280	13,425	35,944	22,569	13,425	Low
Al nazlah al yamaneiah	7,403	7,403	250	30,031	29,919	13,425	Low
Al nuzha	10,223	9,677	9,677	98,960	98,289	73,143	High
Al qryat	15,751	15,639	0	15,751	15,639	250	Low
Al rabwah	1,297	1,297	0	2,513	1,297	23,844	Low
Al rawabe	3,390	1,198	47	18,243	2,608	5,075	Low
Al rawdah	986	140	0	12,899	4,249	7,316	High
Al rehab	1,758	1,404	3,835	18,942	10,890	42,910	Mid
Al rughamah	32609	32609	0	35059	38850	0	Low
Al ruwase	7,633	3,601	947	12,224	8,192	16,731	Low
Al sabeel	14,440	14,440	13,175	29,229	29,172	13,425	Low
Al safa	50,061	7,403	8,890	74,453	27,527	36,557	Mid
Al sahefah	10,270	10,270	8,291	26,188	26,130	13,425	Low
Al salamah	957	0	0	1,942	140	0	Mid

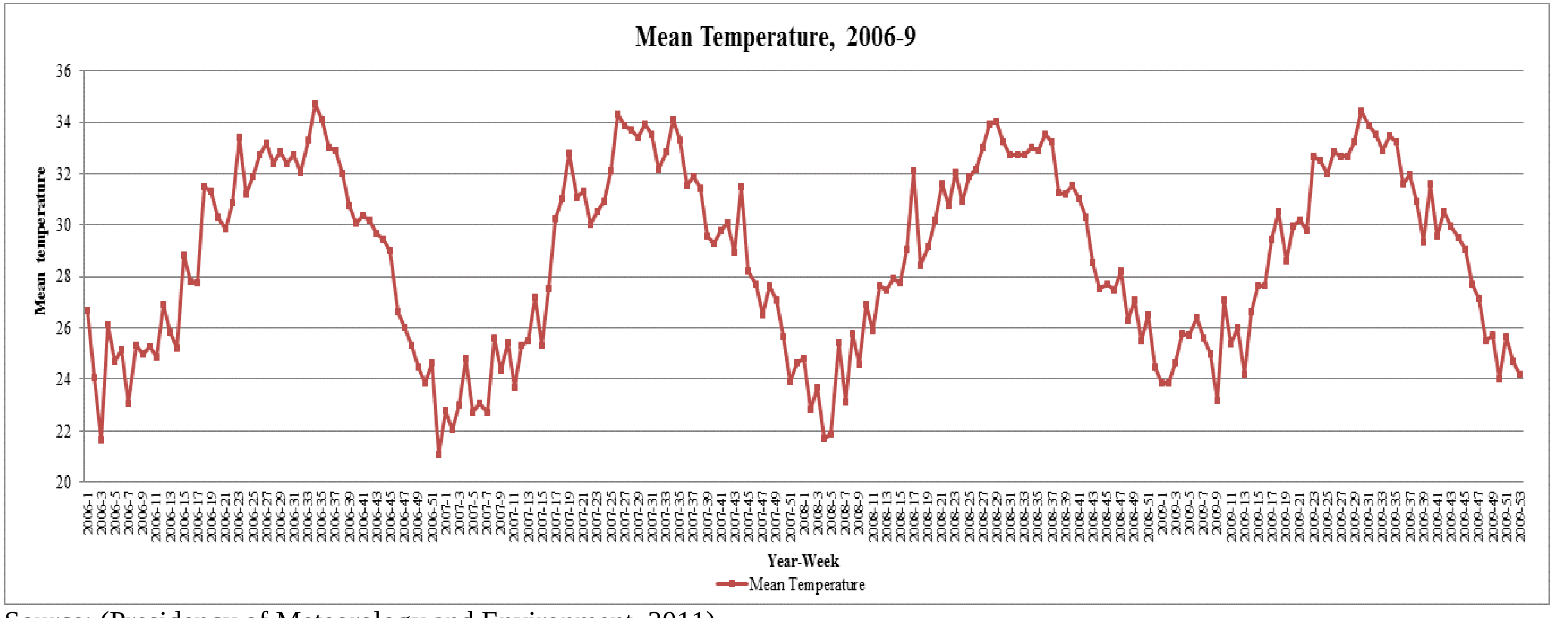
Al senaeya	26,591	26,591	20,878	69,809	69,809	16,0476	Low
Al sharafiah	6,125	5,162	14,112	12,102	8,070	50,512	Low
Al shate	7,274	1,842	1,737	12,533	4,375	3,362	High
Al sulaymaneiah	10,442	0	6,470	14,273	2,284	9,692	Mid
Al thagur	13,375	0	250	33,445	20,003	13,627	Low
Al thalebah	15,751	15,639	0	23,149	22,265	0	Low
Al worood	7,220	7,220	49,020	13,653	13,184	49,020	Mid
Al Zahra	629	0	0	8,889	1,981	1,737	Mid
Bane malek	3,546	1,787	5,437	20,592	11,664	71,369	Low
Betrumeen	14,723	13,846	0	88,693	87,816	27,8213	Low
Buraiman	41,321	39,517	59,701	176,100	174,121	62,186	Mid
Guleel	7,301	7,251	0	23,272	22,395	76,212	Low
Madaen al fahad	13,443	0	259	20,200	6,758	7,230	Low
Meshrefah	1,063	1,063	37,989	11,163	6,919	46,514	Low
Obhur al janoubeiah	0	0	0	14,306	11,569	4,702	Mid
Obhur al shamaliah	0	0	0	0	0	0	High

Appendix 7: Surface water percentage and size in Jeddah City neighbourhood from 2007-2009

Neighbourhoods	**% Surface water**			SES levels
	2007	**2008**	**2008**	
Al ameerfawaz	0.00%	0.00%	0.00%	Mid
Al ammareih	0.00%	0.00%	0.00%	Low
Al andulus	0.15%	0.03%	0.05%	Mid
Al azizeiah	0.11%	0.01%	0.01%	Low
Al bagdadeiah al garbeiah	0.02%	0.00%	0.00%	Mid
Al bagdadeiah al sharqeiah	0.00%	0.00%	0.00%	Mid
Al balad	0.00%	0.00%	0.00%	Low
Al basateen	0.12%	0.00%	0.00%	High
Al bawadi	0.01%	0.00%	0.00%	Mid
Al faysaleiah	0.16%	0.01%	0.02%	Mid
Al fiha	0.59%	0.22%	0.16%	Low
Al hamrah	0.17%	0.04%	0.01%	High
Al hendaweiah	0.03%	0.01%	0.00%	Low
Al jameah	0.27%	0.02%	0.00%	Low
Al jawharah	0.06%	0.00%	0.00%	Mid
Al kandarah	0.00%	0.00%	0.00%	Low
Al khalediah	0.23%	0.00%	0.00%	Mid
Al khomrah	0.46%	0.15%	0.19%	Low
Al mahgar	1.62%	0.54%	2.60%	Low
Al malekabdoulazez airport	0.96%	0.32%	0.23%	Mid
Al marjan	0.00%	0.00%	0.00%	High
Al marwah	0.08%	0.01%	0.23%	Mid
Al mohammadeiah	0.21%	0.06%	0.01%	High
Al naeem	0.01%	0.00%	0.01%	Mid
Al nahdah	2.06%	0.69%	0.29%	High
Al naseem	0.14%	0.03%	0.00%	Mid
Al nazlah al sharqeiah	0.00%	0.00%	0.01%	Low
Al nazlah al yamaneiah	0.00%	0.00%	0.00%	Low
Al nuzha	0.00%	0.00%	0.00%	High
Al qryat	0.37%	0.12%	0.00%	Low
Al rabwah	0.00%	0.00%	0.00%	Low
Al rawabe	0.00%	0.00%	0.00%	Low
Al rawdah	0.03%	0.00%	0.00%	High
Al rehab	0.01%	0.00%	0.02%	Mid
Al rughamah	0.38%	0.20%	0.02%	Low
Al ruwase	0.01%	0.00%	0.02%	Low
Al sabeel	0.00%	0.00%	0.00%	Low
Al safa	0.00%	0.00%	0.00%	Mid
Al sahefah	0.00%	0.00%	0.00%	Low

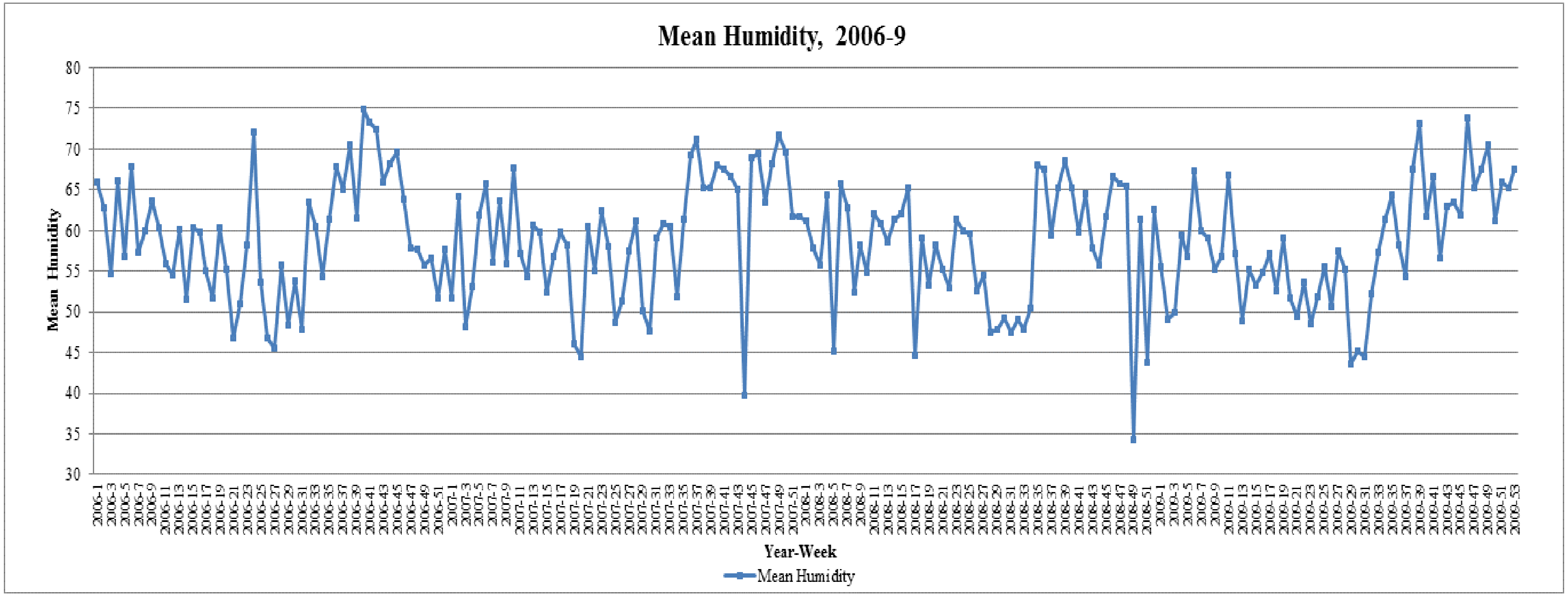
Al salamah	0.00%	0.00%	0.00%	Mid
Al senaeya	0.88%	0.29%	0.65%	Low
Al sharafiah	0.00%	0.00%	0.00%	Low
Al shate	0.07%	0.02%	0.00%	High
Al sulaymaneiah	0.00%	0.00%	4.42%	Mid
Al thagur	0.00%	0.00%	0.00%	Low
Al thalebah	1.54%	0.51%	0.00%	Low
Al worood	0.31%	0.10%	0.11%	Mid
Al zahra	0.43%	0.14%	1.35%	Mid
Bane malek	0.03%	0.01%	0.00%	Low
Betrumeen	0.03%	0.00%	0.06%	Low
Buraiman	0.50%	0.17%	0.00%	Mid
Guleel	2.14%	0.71%	0.44%	Low
Madaen al fahad	0.00%	0.00%	0.00%	Low
Meshrefah	0.00%	0.00%	0.00%	Low
Obhur al janoubeiah	0.05%	0.02%	0.00%	Mid
Obhur al shamaliah	0.04%	0.00%	0.03%	High

Appendix 8: Mean temperature, 2006-2009



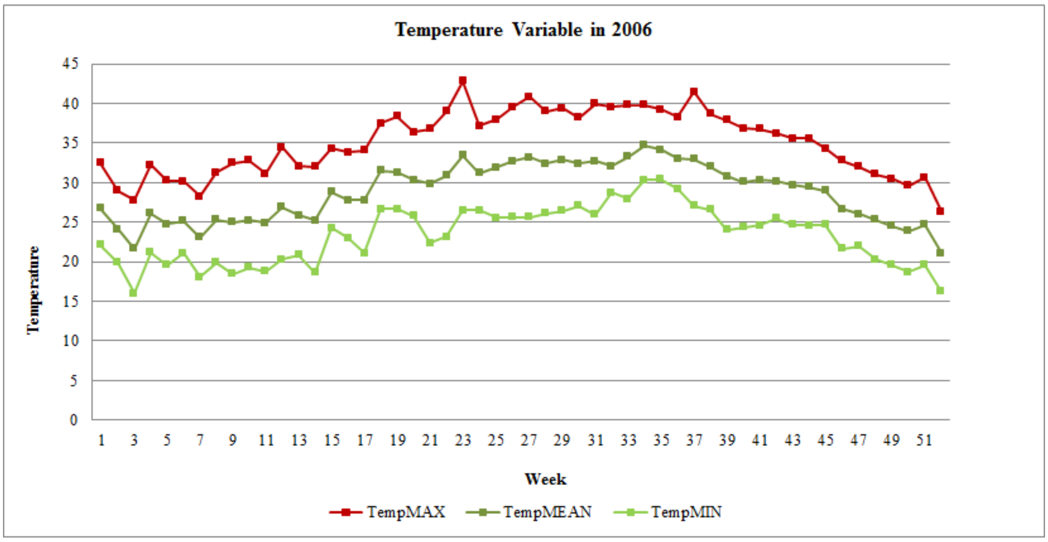
Source: (Presidency of Meteorology and Environment, 2011)

Appendix 9: Mean humidity, 2006-2009



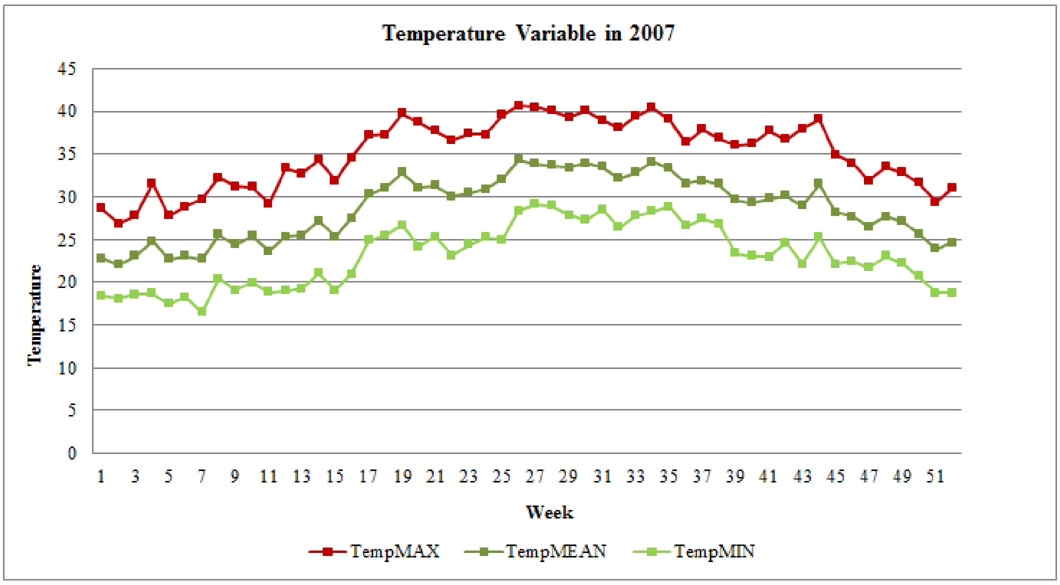
Source: (Presidency of Meteorology and Environment, 2011)

Appendix 10: Average weekly temperature variable shown for 2006



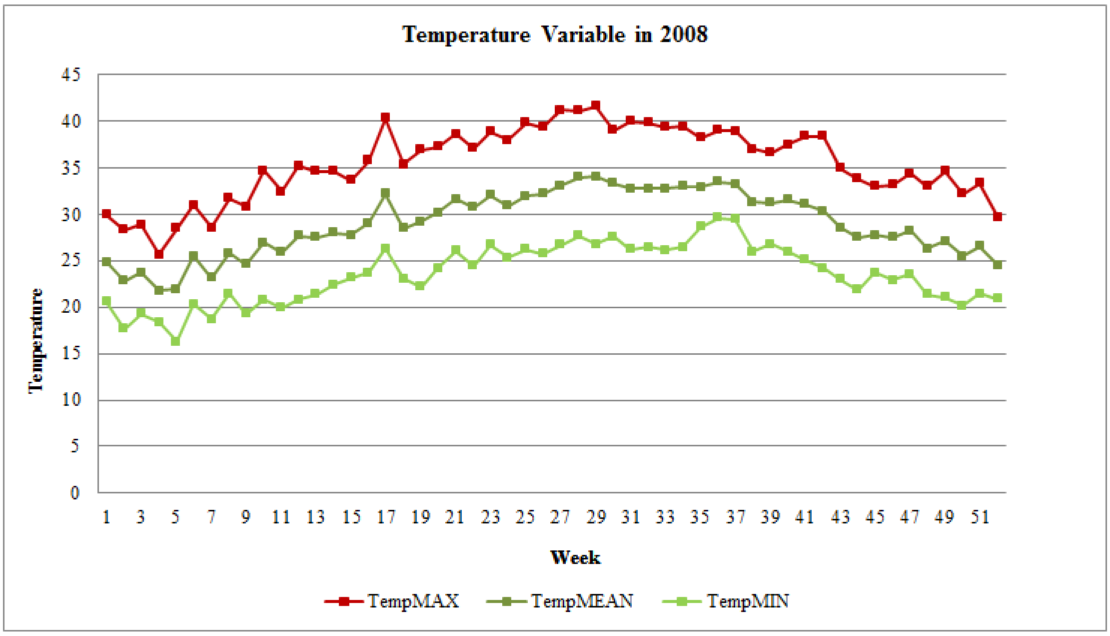
Source: (Presidency of Meteorology and Environment, 2011)

Appendix 11: Average weekly temperature variable shown for 2007



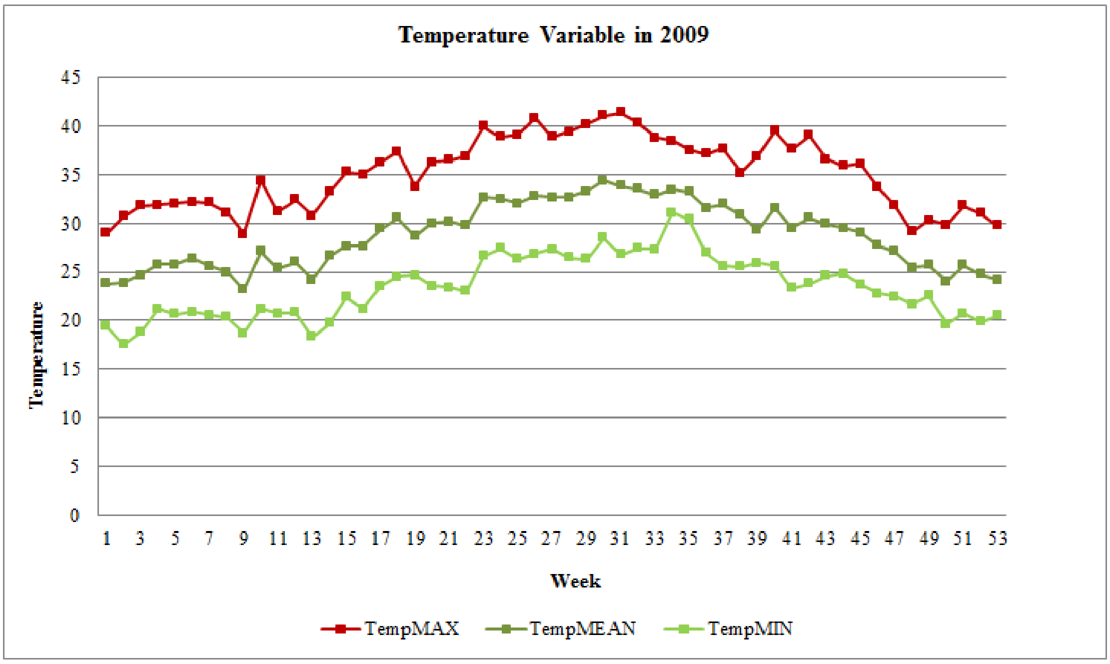
Source: (Presidency of Meteorology and Environment, 2011)

Appendix 12: Average weekly temperature variable shown for 2008



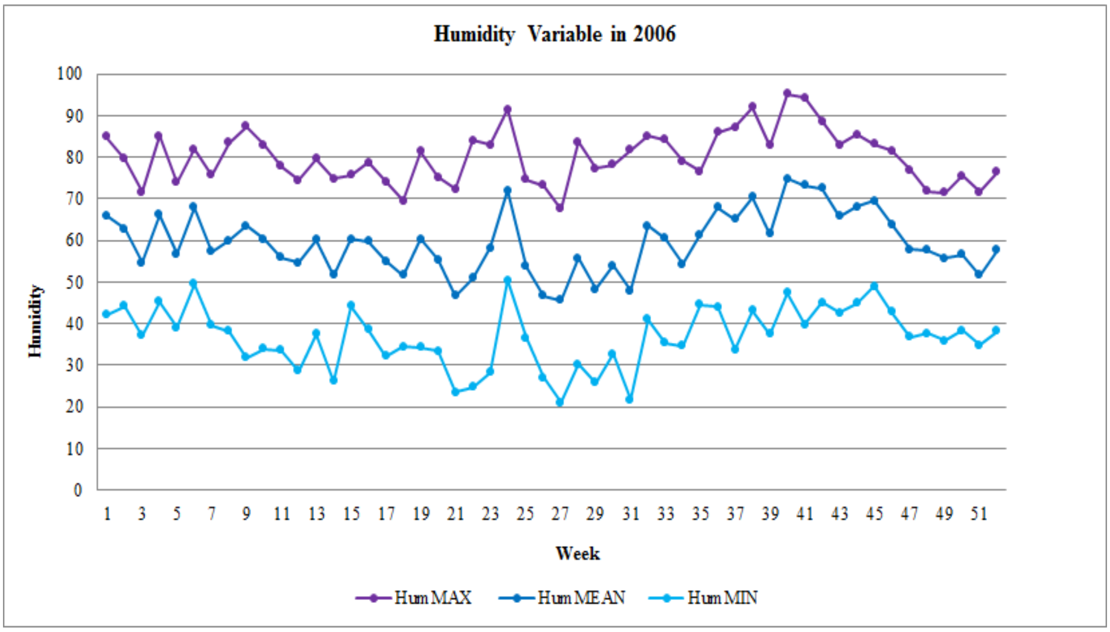
Source: (Presidency of Meteorology and Environment, 2011)

Appendix 13: Average weekly temperature variable shown for 2009



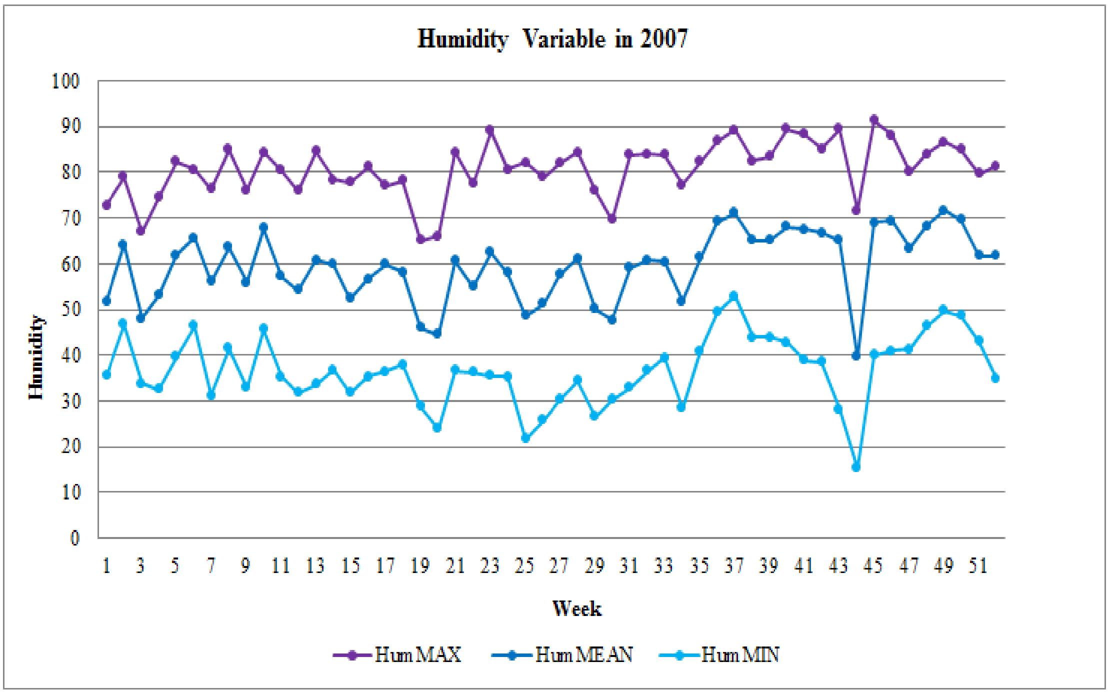
Source: (Presidency of Meteorology and Environment, 2011)

Appendix 14: Average weekly humidity variable shown for 2006



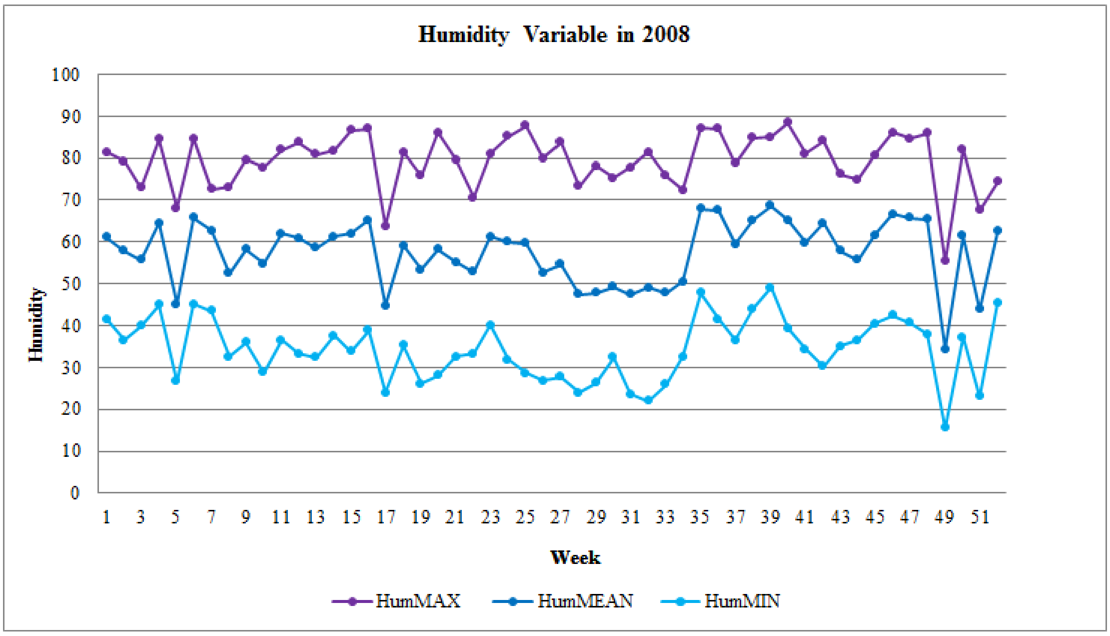
Source: (Presidency of Meteorology and Environment, 2011)

Appendix 15: Average weekly humidity variable shown for 2007



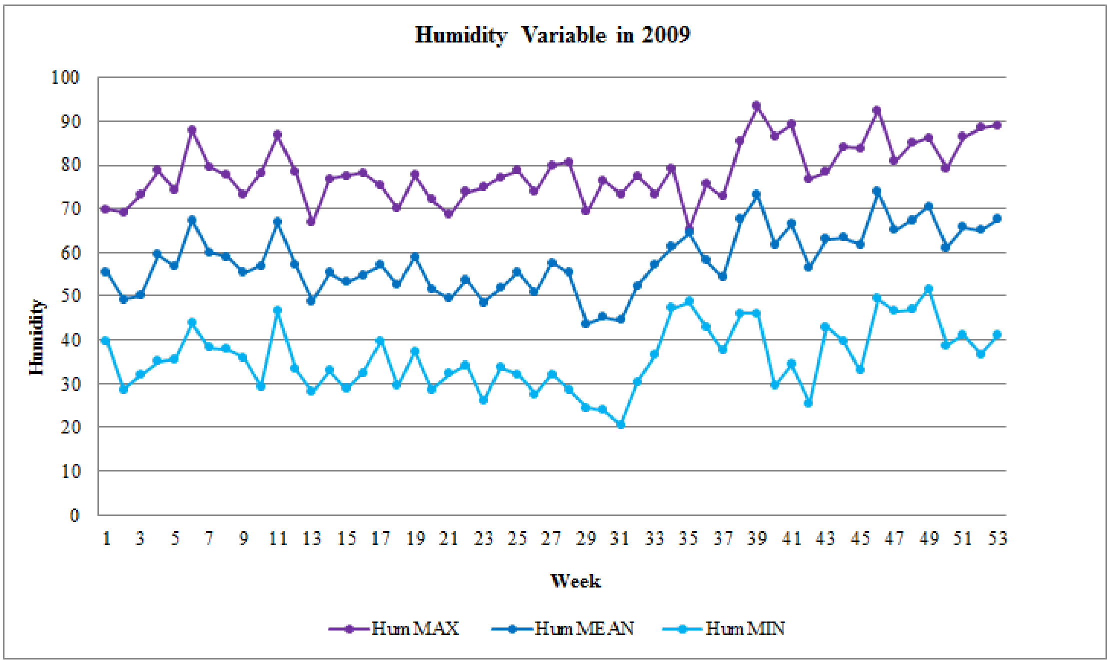
Source: (Presidency of Meteorology and Environment, 2011)

Appendix 16: Average weekly humidity variable shown for 2008



Source: (Presidency of Meteorology and Environment, 2011)

Appendix 17: Average weekly humidity variable shown for 2009



Source: (Presidency of Meteorology and Environment, 2011)

Appendix 18: Quartile for averaged maximum weekly temperature and weekly dengue cases 2006-2009

Quartile of Averaged Maximum Weekly temperature	Quartile of Weekly Dengue Cases				Linear by Linear Association	Chi-Square	*p*<
	0-2	3-8	9-24	25-121			
25.60-31.94	8 15.40%	19 36.50%	21 40.40%	4 7.70%	0.112	26.5	0.00
31.95-35.86	10 19.20%	13 25.00%	12 23.10%	17 32.70%			
35.87-38.66	16 30.20%	15 28.30%	5 9.40%	17 32.10%			
38.67-42.81	6 11.50%	14 26.90%	14 26.90%	18 34.60%			

Appendix 19: Quartile for averaged weekly temperature and weekly dengue cases 2006-2009

Quartile of Averaged Weekly Temperature	Quartile of Weekly Dengue Cases				Linear by Linear Association	Chi-Square	*p*<
	0-2	3-8	9-24	25-121			
21.10-25.58	7 13.50%	20 38.50%	18 34.60%	7 13.50%	0.238	15.0	0.00
25.59-29.30	12 23.10%	11 21.20%	14 26.90%	15 28.80%			
29.31-31.98	13 24.50%	16 30.20%	7 13.20%	17 32.10%			
31.99-34.70	8 15.40%	14 26.90%	13 25.00%	17 32.70%			

Appendix 20: Quartile for averaged minimum weekly temperature and weekly dengue cases2006-2009

Quartile of Averaged Minimum Weekly Temperature	Quartile of Weekly Dengue Cases				Linear by Linear Association	Chi-Square	*p*<
	0-2	3-8	9-24	25-121			
16.03-20.59	7 13.50%	18 34.60%	18 34.60%	9 17.30%	0.658	9.4	0.4
20.60-23.35	10 19.20%	14 26.90%	14 26.90%	14 26.90%			
23.36-26.29	12 22.60%	17 32.10%	9 17.00%	15 28.30%			
26.30-31.09	11 21.20%	12 23.10%	11 21.20%	18 34.60%			

Appendix 21: Quartile for averaged maximum weekly humidity and weekly dengue cases 2006-2009

Quartile of Averaged Maximum Weekly Humidity	Quartile of Weekly Dengue Cases				Linear by Linear Association	Chi-Square	*p*<
	0-2	3-8	9-24	25-121			
55.29-75.42	5 9.60%	12 23.10%	14 26.90%	21 40.40%	0.00	23.5	0.00
75.43-79.56	5 9.40%	19 35.80%	11 20.80%	18 34.00%			
79.57-84.42	12 23.50%	16 31.40%	12 23.50%	11 21.60%			
84.43-95.14	18 34.00%	14 26.40%	15 28.30%	6 11.30%			

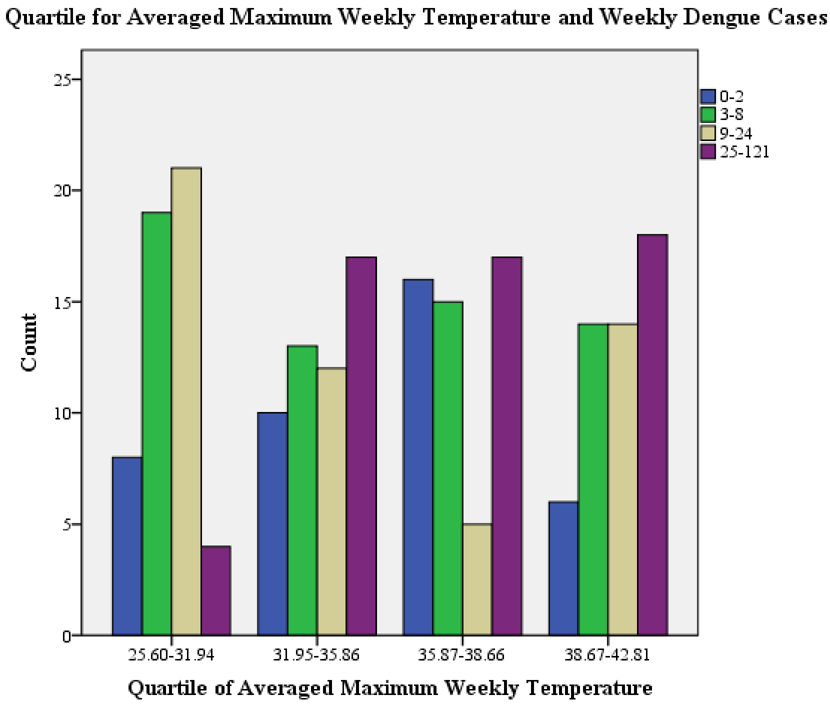
Appendix 22: Quartile of average weekly humidity and weekly dengue cases 2006-2009

Quartile of Average Weekly Humidity	Quartile of Weekly Dengue Cases				Linear by Linear Association	Chi-Square	P<
	0-2	3-8	9-24	25-121			
34-53.78	5 9.60%	13 25.00%	11 21.20%	23 44.20%	0.00	34.8	0.00
53.79-59.13	5 9.60%	15 28.80%	13 25.00%	19 36.50%			
59.14-64.42	10 19.20%	18 34.60%	12 23.10%	12 23.10%			
64.43-75	20 37.70%	15 28.30%	16 30.20%	2 3.80%			

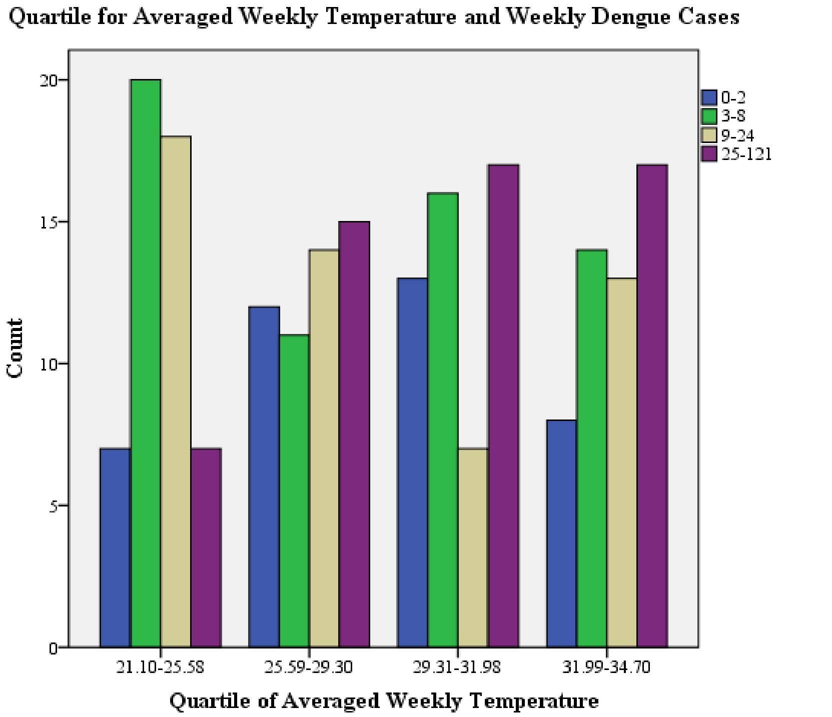
Appendix 23: Quartile for averaged minimum weekly humidity and weekly dengue cases, 2006-2009

Quartile of Averaged Minimum Weekly Humidity	Quartile of Weekly Dengue Cases				Linear by Linear Association	Chi-Square	P<
	0-2	3-8	9-24	25-121			
15-31.42	5 9.60%	12 23.10%	11 21.20%	24 46.20%	0.00	34.0	0.00
31.43-35.99	5 9.60%	16 30.80%	11 21.20%	20 38.50%			
36-41.06	14 26.40%	19 35.80%	12 22.60%	8 15.10%			
41.07-53	16 30.80%	14 26.90%	18 34.60%	4 7.70%			

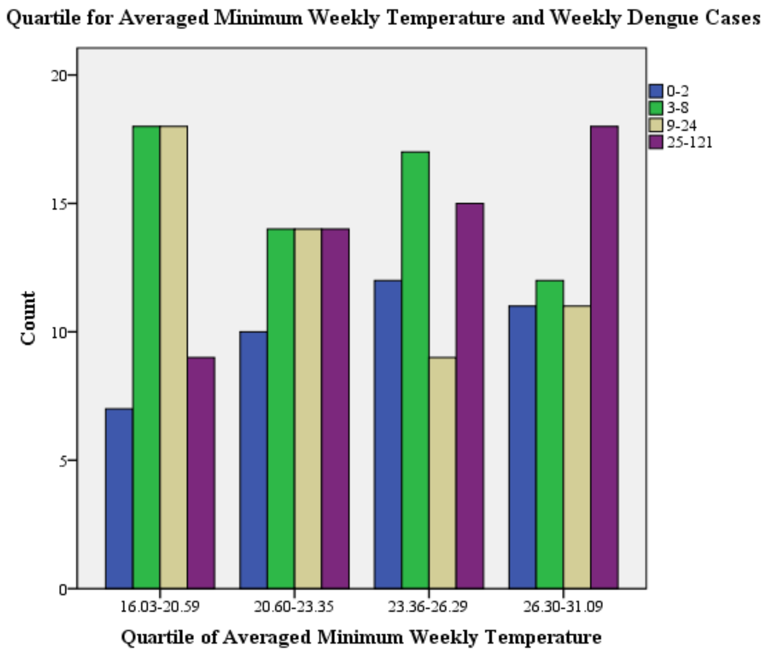
Appendix 24: Quartile for averaged maximum weekly temperature and weekly dengue cases 2006-2009



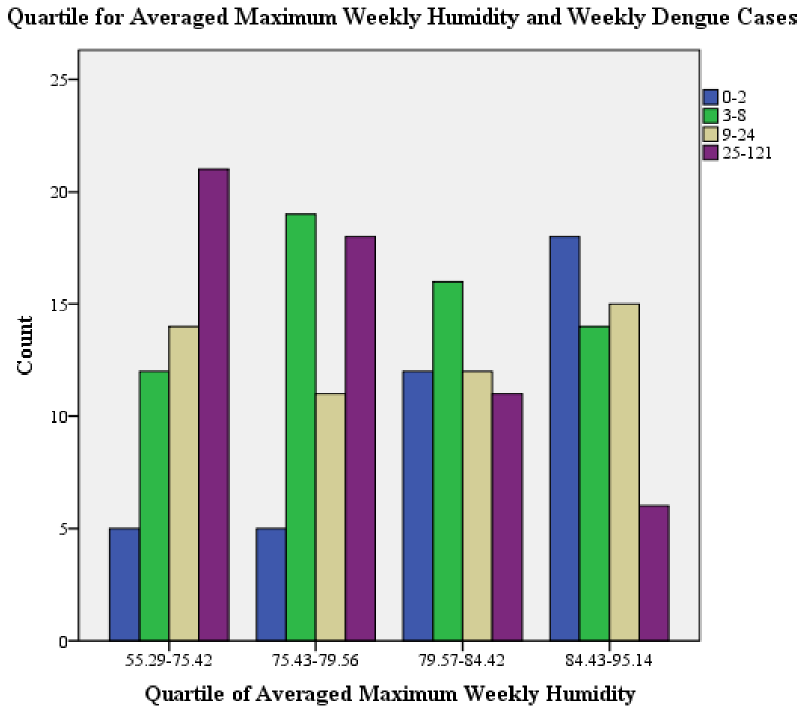
Appendix 25: Quartile for averaged weekly temperature and weekly dengue cases 2006-2009



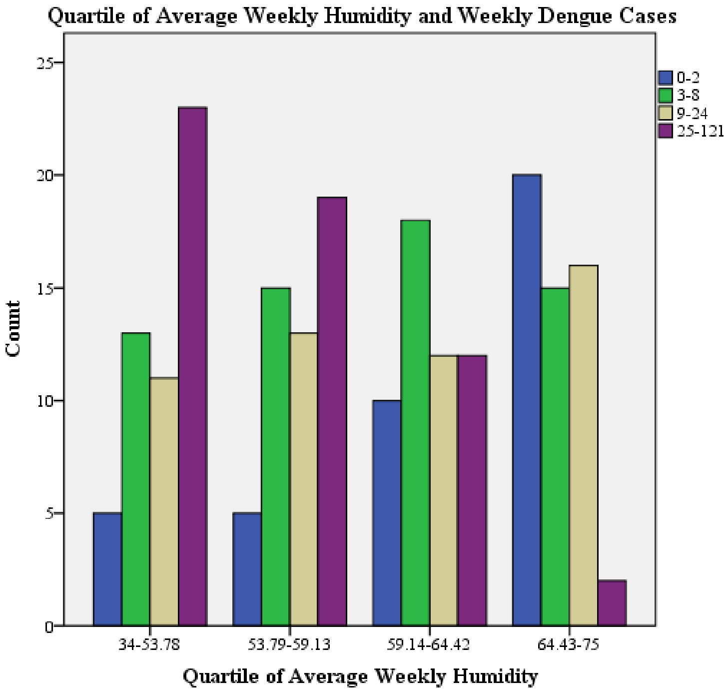
Appendix 26: Quartile for averaged minimum weekly temperature and weekly dengue cases 2006-2009



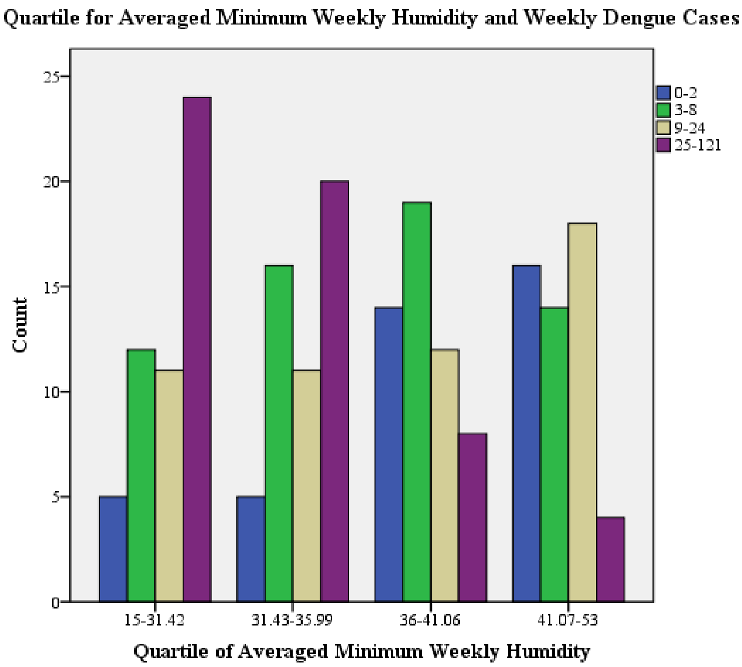
Appendix 27: Quartile for averaged maximum weekly humidity and weekly dengue cases 2006-2009



Appendix 28: Quartile of average weekly humidity and weekly dengue cases 2006-2009



Appendix 29: Quartile for averaged minimum weekly humidity and weekly dengue cases, 2006-2009



Appendix 30: Cross tabulation for averaged minimum weekly temperature and weekly dengue cases 2006-2009

Averaged Minimum Weekly Temperature	Dengue Fever Cases		Odds Ratio
	<2 cases	>25 cases	
<20.59	7	9	1
20.60-23.35	10	14	1.09
23.36-26.29	12	15	0.97
>26.30	11	18	1.27

Appendix 31: Cross tabulation for averaged weekly temperature and weekly dengue cases 2006-2009

Averaged Weekly Temperature	Dengue Fever Cases		Odds Ratio
	<2 cases	>25 cases	
<25.58	7	7	1
25.59-29.30	12	15	1.25
29.31-31.98	13	17	1.31
>31.99	8	17	2.12

Appendix 32: Cross tabulation for average weekly humidity and weekly dengue cases 2006-2009

Average Weekly Humidity	Dengue Fever Cases		Odds Ratio
	<2 cases	>25 cases	
<53.78	5	23	1
53.79-59.13	5	19	0.83
59.14-64.42	10	12	0.26
>64.43	20	2	0.02

Appendix 33: Cross tabulation for averaged minimum weekly humidity and weekly dengue cases 2006-2009

Averaged Minimum Weekly Humidity	Dengue Fever Cases		Odds Ratio
	<2 cases	>25 cases	
<31.42	5	24	1
31.43-35.99	5	20	0.83
36-41.06	14	8	0.12
>41.07	16	4	0.05